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The Glacidorbidae (Mollusca: Gastropoda: Heterobranchia) of Australia

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ABSTRACT. The heterobranch gastropod family Glacidorbidae (?Pulmonata) is known only from temperate Australia and Chile. The Australian taxa are reviewed and three new genera, *Benthodorbis, Striadorbis* and *Tasmodorbis* are described based on differences in their shells, especially the protoconchs, and in their opercula and radulae. Nineteen species of Australian glacidorbids are recognised, all but four of them new. Of the four Australian species previously included in *Glacidorbis*, only two, *G. hedleyi* (Iredale) from New South Wales and Victoria, and *G. occidentalis* Bunn & Stoddart from south Western Australia, are retained in that genus. Eleven new species of *Glacidorbis* are described, seven from Tasmania (*G. bicarinatus, G. catomus, G. atrophus, G. decoratus, G. costatus, G. tasmanicus* and *G. circulus*), one (*G. isolatus*) from New South Wales, two (*G. otwayensis* and *G. rusticus*) from Victoria and one (*G. troglodytes*) from South Australia. *Striadorbis* contains the Tasmanian *S. pedderi* (Smith), and two new species, *S. spiralis* from western Victoria and *S. janetae* from Tasmania. *Benthodorbis* contains two species, both from old lakes in Tasmania; *B. pawpela* (Smith) from Great Lake and *B. fultoni* from Lake Sorell. *Tasmodorbis* contains a single species found in western Tasmania, *T. punctatus*, unique in having internal shell pores. *Glacidorbis costatus* is known only from Pulbeena Swamp in NW Tasmania and appears to be recently extinct, possibly as a result of draining of the swamp in the early part of this century. A cladistic analysis with the South American member of the family, *Gondwanorbis*, as the outgroup, supports the monophyly of the genera recognised.

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Small-sized Australian freshwater molluscs have, in recent years, been shown to be much more diverse than previously imagined. Nearly all of this diversity is contained within the caenogastropod family Hydrobiidae (see Ponder, 1991 and Ponder & de Keyzer, 1998 for review), while other families of small-sized freshwater gastropods such as the Assimineidae, Bithyniidae, Planorbidae and Glacidorbidae are known to contain a several undescribed taxa. This paper revises the taxa included in the Glacidorbidae.

A tiny flat-spired gastropod, *Glacidorbis hedleyi*, was described by Iredale (1943) from Blue Lake, Mount Kosciuszko, NSW. Iredale included his new taxon in the basommatophoran pulmonate family Planorbidae but Meier-Brook & Smith (1976) showed that the genus was operculate and reviewed the known species. While they suggested similarities with the hydrobiids, they did not make any decision on the placement of the genus pending anatomical investigation and Smith (1979) placed

Glacidorbis "close to the Hydrobiidae" while Smith & Kershaw (1979, 1981) included it in the Hydrobiidae. Glacidorbidae was introduced by Ponder (1986) who described the anatomy of *G. hedleyi* and erected a new superfamily for the group that he considered to be atypical, probably paedomorphic, pulmonates. A pulmonate relationship was accepted by Visser (1988), although this author suggested that it had a basal position in the basommatophorans, rather than "the suggestion of Ponder (1986) that Glacidorbidae represent a neotenous group derived from the Lymnacea". In fact, Ponder (p. 77) argued that *Glacidorbis* may be derived from "proto-pulmonate" ancestors of the Amphibolacea-Ellobiacea, representing a freshwater incursion quite independent of the major lymnaeoidean radiation. In contrast to this view of the relationship of the family, Haszprunar (1988), Haszprunar & Huber (1990) and Huber (1993) argued that because of the lack of a typical pentaganglionate nervous system, a pneumostome, procerebrum and dorsal bodies, *Glacidorbis* was an "allogastropod", a grouping introduced by Haszprunar (1985) for the "lower heterobranchs" and equivalent to Heterostropha as used by Ponder & Warén (1988). Unpublished sperm ultrastructural data (J. Healy, pers. comm.) suggest relationships with basal pulmonates. The pulmonate placement of this group was provisionally followed by Stanisic (1998) in his review of the family for the "Fauna of Australia". The group was placed in a separate "order" (Glacidorbiformes) within the "subclass Sinistrobranchia" by Starobogatov (1988) but this classification has not been considered seriously by other workers. We consider a pulmonate relationship is still probable and that *Glacidorbis* is highly paedomorphic, a factor explaining the absence of many of the typical pulmonate characters (see also Ponder & Lindberg, 1997). This assessment could be readily tested using molecular data but is beyond the scope of this paper.

Only four species assigned to *Glacidorbis* have previously been described from Australia, two of these (*Valvata*(?) *pedderi* Smith, 1973; *Glacidorbis pawpela* Smith, 1979) from Tasmania, one from SW Australia (*G. occidentalis* Bunn & Stoddart, 1983) and *G. hedleyi* (Iredale, 1943) from the Great Dividing Range of Victoria and New South Wales. Smith & Kershaw (1981) mapped the distributions of the species of *Glacidorbis* known at that time and Ponder (1996) mapped *Glacidorbis* records in NE Tasmania noting that they comprised "two or three undescribed species".

A few studies have been made on the biology and ecology of these animals, other than basic habitat and brooding. Ponder (1986) described the reproduction and feeding of *Glacidorbis hedleyi*, Boulton & Smith (1985) described the ecological requirements of that species, and Bunn *et al.* (1989) described the ecology of *G. occidentalis* Bunn & Stoddard, 1983.

Material and methods

Material was collected by hand either by washing substrate (e.g., vegetation, roots, wood, rock, gravel) into a plastic bowl or small bucket or by using a hand sieve, with a mesh size of c. 1 mm, and sweeping the vegetation. The resulting sample was gently elutriated, the light material discarded. A few menthol crystals were added to the sample which was left to stand overnight in an attempt to relax at least some of the specimens. The sample was then bulk fixed in c. 10% neutralised formalin, later transferred to 5% buffered formalin. Specimens were sorted from the bulk sample using a dissecting microscope.

Material from the collections of various institutions was also utilised during the study (see list of abbreviations).

Although the radulae proved difficult to manipulate, they were mounted using standard methods. The buccal masses were dissolved using a strong solution of potassium hydroxide, the radulae were removed, washed in distilled water and air dried to glass cover slips which were then fixed to SEM stubs. Shells and opercula were mounted using standard methods. Most of the material was examined using a Cambridge 120 SEM, although some was examined using a LEO 435VP SEM (both with Robinson backscatter detector). Images were captured digitally.

A cladistic analysis was conducted using the data matrix given in Table 1 with PAUP*4b2 (Swofford, 1999) and the default heuristic search options and 100 random iterations. *Gondwanorbis* was defined as the outgroup. Bremer support was calculated using TreeRot ver. 2 (Sorenson, 1999).

Abbreviations

Shell measurements: aph—aperture height; apw—aperture width; dmax—maximum diameter; dmin—minimum diameter; mdht—height (at mid point of shell); mxht—maximum height of shell; whl—total number of whorls.

Collectors: ACM—Alison C. Miller; BJS—Brian. J. Smith; DLB—Des L. Beechey; FEH—Frank E. Hermans; GAC—Gerard A. Clark; IFCT—Inland Fisheries Commission, Tasmania; JH—Jane Hall; JHW—Janet H. Waterhouse; JMP—Julie M. Ponder; RdK—Roger de Keyzer; SAC—Stephanie A. Clark; WFP—Winston F. Ponder; WFPj—Warwick F. Ponder.

Institutions: AMS—Australian Museum, Sydney; MV—Museum of Victoria; QVM—Queen Victoria Museum, Launceston; SAM—South Australian Museum, Adelaide; TM—Tasmanian Museum, Hobart; WAM—Western Australian Museum.

Miscellaneous: AMG—Australian Map Grid, cond.—conductivity (in mS/cm at 12°C); NP—National Park; SF—State Forest.

Taxonomy

The following diagnosis of the monotypic superfamily and family are modified from Ponder (1986).

Glacidorboidea and Glacidorbidae Ponder, 1986

Diagnosis. Shell small to minute (most species less than 2 mm in maximum diameter, one species slightly less than 4 mm), dextrally coiled, orthostrophic to hyperstrophic, with flat or near flat spire to planispiral, with wide, shallow umbilicus. Operculum circular to oval, multispiral to

paucispiral, with central to eccentric nucleus. Jaw with dorsal and ventral elements. Radula with large central teeth bearing several sharp cusps on a pointed mesocone, with broader, arched base lacking additional cusps. Lateral teeth vestigial or narrow and small; marginal teeth absent. Head-foot (details only known for a few species of *Glacidorbis*) with long cephalic tentacles with eyes in middle of bases, foot posteriorly bifid, anteriorly with lateral processes; snout short and very broad. Pallial cavity (anatomical details only known for two species in two genera, *Glacidorbis* and *Striadorbis* n.gen., and superficially for a third genus—*Gondwanorbis*) widely open, not modified as a lung, with ciliated ridge on right side. Anus and female genital opening within pallial cavity. Stomach simple, intestine short and straight, anus opening about mid-way along pallial cavity. Pericardium at posterior end of pallial cavity. Nerve ring anterior to buccal bulb, visceral loop with slight chiastoneury and lacking distinct parietal ganglia ("triganglionate" condition). Protandrous, and brooding. Female system partly pallial, lacking separate bursa copulatrix, with several large embryos brooded in mantle cavity. Prostate gland separate from vas deferens, penis narrow and small, completely invaginated, with large sucker or knob-like glands in the large praeputium.

Remarks. *Glacidorbis* shares many anatomical characters with other heterobranchs (Ponder, 1986), as indicated by the following characters in particular: the kidney is in the mantle roof, the ctenidium is absent, the oesophagus is simple (lacking glands and dorsal folds), the snout is short and broad and fused to the dorsal part of the anterior foot, the eyes are in the middle of the tentacle bases, and the spermatozoa are spirally ridged. The ciliated mantle fold may be homologous with the ciliated ridges seen in many aquatic heterobranchs (Haszprunar, 1988). Dorsal and ventral jaw elements and the organisation of the reproductive system, particularly the penial apparatus, are characters that strongly suggest pulmonate relationships.

Three new genera of glacidorbids are described below. The monophyly of the four Australian genera is supported in a cladistic analysis (see Discussion for details). A key to the five genera now recognised in the family is given.

Key to genera

1 teleoconch growth lines orthocline 2–4

—— teleoconch growth lines prosocline ..... *Benthodorbis*

2 shell keeled mid dorsally (and sometimes) mid ventrally 3,4

—— shell evenly convex dorsally and ventrally 3,4

—— shell keeled in middle of periphery ..... *Gondwanorbis*

3 operculum paucispiral with subcentral to eccentric nucleus; with or without external pustules 5

—— operculum paucispiral with central nucleus; with external pustules ..... *Striadorbis*

—— operculum multispiral with central nucleus; without external pustules ..... *Tasmodorbis*

4 protoconch with pustules or pits over whole surface ..... *Glacidorbis*

—— protoconch with pustules on clearly demarcated initial portion followed by smooth portion ..... *Glacidorbis*

—— protoconch with pustules in early part, followed by well-spaced spiral threads ..... *Striadorbis*

—— protoconch of axial rugae crossed by numerous spiral cords with linear interspaces ..... *Tasmodorbis*

—— protoconch with fine spiral and axial threads over whole surface ..... *Benthodorbis*

5 operculum with external pustules ..... *Glacidorbis*

—— operculum lacking external pustules ..... *Benthodorbis*

Glacidorbis Iredale, 1943: 227

Type species. *Glacidorbis hedleyi* Iredale, 1943, by original designation.

Diagnosis. Shell orthostrophic, near planispiral. Protoconch terminated by abrupt change in sculpture, lacking varix; sculptured with pustules or pits over whole surface, or on initial portion only with remaining part smooth. Teleoconch whorls evenly convex or ridged or keeled near mid-dorsally and near mid ventrally, sculptured with orthocline axial growth lines or ridges, sometimes also with spiral sculpture. Operculum paucispiral, with subcentral to eccentric nucleus, and surface covered with minute pustules. Radula with equal-sized cusps on mesocone and major articulatory thickening on base at anterior edge of each tooth, or subequal with posterior articulation.

Glacidorbis hedleyi Iredale, 1943

Glacidorbis hedleyi Iredale, 1943: 227; Meier-Brook & Smith, 1976: 192, figs. 8–11; Boulton & Smith, 1985: 123–126, fig. 1; Smith, 1979: 123, fig. 2 (part); Smith & Kershaw, 1979: 40 (fig. in text); Ponder, 1986: 53–81, figs. 1–20, 22A; Smith, 1992: 223–224.

Type material. LECTOTYPE designated by Meier-Brook & Smith, 1976: 192; damaged and mounted on SEM stub, AMS C100597. PARALECTOTYPES: 40, AMS C22789.

Type locality. Blue Lake, Mount Kosciusko, NSW, 36°24'S 148°19'E, dredged from 35 ft (10.7 m), C. Hedley, 1906.

Additional material examined. NEW SOUTH WALES: stn C780N-A, Dawson Spring, Mt Kaputar, 30°17'S 150°9.5'E, on sedges, 10 m from spring source, 8 Nov 1983, P.H. Colman (many, AMS C140421); stn C780N-B, same loc., date & coll., 1343 m, in small rapids on sedges, 30 m from spring source (many, AMS C140423); stn C780N-C, same loc., date & coll., on plants and rocks in pool, c. 200 m from spring source (many, AMS C140426); same loc., date and coll., (1, AMS C362933); same loc., just above little dam opposite Ranger Headquarters, 1500 m, in sedges etc., 27 Nov 1991, SAC (14, AMS C351554); stn AM9, N of Dorrigo, Moonpar National Forest, off Mills Rd, Moonmerri Ck just above Nymboida River junction, 30°11.52'S 152°41.5'E, 415 m, under stones, 11 Mar 1981, WFP & O.L. Griffiths (2, AMS C128705); stn 5, tributary of Bobo Creek, NE of Dorrigo, 30°13'S 152°50'E, 500 m, rainforest and hoop pine, small flowing stream, 11 Mar 1981, WFP, J. Stanisic & O.L. Griffiths (3, AMS C361956); stn 16HV, Tombolla Creek at N end of Tuggolo Forest Way, 31°27'S 151°24.5'E, small stream, moss covered rocks, 23 Feb 1988, WFP & JMP (many, AMS C309358); stn 13HV, South Head Ck, on track 500 m SW from road between Snowball Rd and Nundle Forest Way, Nundle SF, 31°27.04'S 151°16.4'E, 1190 m, on moss and other weeds in clumps of saturated moss, 23 Feb 1988, WFP (several, AMS C306339); stn 10HVC(A), E of Nundle, Nundle SF, Ponderosa Forest Park, Four Mile Ck tributary, c. 200 m E of forestry camp, 31°28.05'S 151°15.46'E, 1240 m, small slow flowing clear stream, moss and liverworts on rocks, 23 Feb 1988, WFP (1, AMS C306338; 18, AMS C361945); stn 10HVB, same loc., pond with boulders and sand, 23 Feb 1988, WFP (20, AMS C361964); stn 10HVD, same loc., date & coll., spring with boulders and sand (many, AMS C361974); stn 12HV, Duncans Creek, Zircon Gully Picnic Area, Nundle SF, just off Nundle Forest Way, 31°28.14'S 151°14.18'E, 23 Feb 1988, WFP & JMP (many, AMS C309349); stn MN7, Norfolk Falls, Warung SF, Liverpool Range, 31°44'S 150°0'E, under rock in quiet side branch of creek above falls, 6 Nov 1985, JHW (1, AMS C303281); stn BT1385, swamp on Boggy Swamp Ck tributary, beside Pheasant Ck Rd, 2.5 km E of Thunderbolts Trail, Barrington Tops SF, 31°53.24'S 151°31.52'E, cutting grass beside road, 28 Mar 1985, WFP (many, AMS C354033, AMS C306342); stn BT1985, Paddys Ck, S Green Gap, on trail between Paddys Ck and Barrington Trails, Stewarts Brook SF, 31°55.66'S 151°26.04'E, in weed and seepage at edge, 28 Mar 1985, WFP (many, AMS C306336); stn BT002, Barrington Tops, Polblue Swamp, 31°57.4'S 151°25.41'E, in swamp, amongst moss and macrophytes, 20 Dec 1997, WFP (many, AMS C365715); stn BT2085, Polblue Swamp, Barrington Tops, 31°57.4'S 151°25.7'E, *Sphagnum*-sedge swamp, 28 Mar 1985, WFP (11, AMS C306335); stn MN31, small tributary of Cobcroft Creek, Werrikimbe NP, E of Walcha, 31°14'S 152°10'E, rainforest, under rocks in gravelly runs, 10 Nov 1985, I. Loch & JHW (5, AMS C361961); stn 24HV, Cobcroft Creek, at Cobcroft Rest Area, Werrikimbe NP, 31°14.833'S 152°10.667'E, rainforest, mossy stones and trickle, liverworts, 25 Feb 1988, WFP & JMP (several, AMS C309368); stn 25HV, swamp from top ridge, Fenwicks Rd, 2 km N from Fenwicks River Crossing, Doyles River SF, 31°18'S 152°1.417'E, swamp, 25 Feb 1988, WFP & JMP (many, AMS C309369); stn 19HV, spring c. 1.5 km from N entry to Riamukka SF, S side of Dennes Sugarloaf Trig., 31°18.25'S 151°48.617'E, duck weed and algae, 24 Feb 1988, WFP & JMP (2, AMS C309364); stn 22HV, small creek on Enfield Rd, Enfield SF, 1 km NW from camp, 31°19.45'S 151°51.933'E, 1060 m, on liverworts (dislodged and submerged), 24 Feb 1988, WFP (many, AMS C361958); stn 20HV, Nundle Creek just below picnic area, 31°20'S 151°51.967'E, in weed, 24 Feb 1988, WFP & JMP (many, AMS C309365); stn 18HV, at edge of Riamukka SF, to W of Brackendale Rd, N of Nowendoc, 31°21.883'S 151°41.417'E, small creek emerging from cutting grass swamp, 23 Feb 1988, WFP & JMP (several, AMS C309361); stn E96-13, NW of Nowendoc, Wild Cattle Ck at Millers Rd, 31°27.167'S 151°34.75'E, small swift stream in leaves etc. in Nowendoc SF, 8 Apr 1996, WFP (many, AMS C311580); stn E96-12, Watts Ck, Nowendoc SF, NW of Nowendoc, 31°29.5'S 151°37'E, in small side channel of swiftly flowing creek with mud and weed, 7 Apr 1996, WFP (several, AMS C311232); stn 17HV, tributary of Back Creek, Tuggolo SF, on Tuggolo Forest Way, 31°30.91'S 151°25.66'E, swampy edges, moss covered stones, 23 Feb 1988, WFP & JMP (6, AMS C309360); stn 1HV, Fern Tree Gully, N of Rylstone, 32°39.5'S 150°2.5'E, small boggy seepages, 21 Feb 1988, WFP & JMP (several, AMS C309321); stn BT2285, The Big Hole, Barrington River, Barrington Tops NP, 32°2.02'S 151°28.17'E, 1390 m, large pool, stream and seeps, 28 Mar 1985, WFP (several, AMS C306337); Gloucester River at Gloucester Tops Rd., 32°5.9'S 151°35.4'E, in swamp, 27 Mar 1985, WFP (many, AMS C306334); Burraga Swamp, Allyn Range, Barrington Tops NP, 32°6.7'S 151°25.6'E, in humus/peat and under logs, 20 Feb 1983, M. Shea & E. Cameron (10, AMS C137729); NW of Dungog, Barrington Tops NP, Allyn Range, Burraga Swamp, 32°6.7'S 151°25.6'E, in damp peat and moss beside log, Feb 1983, M. Shea (many, AMS C306332); Paterson River tributary, S of Burraga Swamp, SSW of Mt Lumeah, Barrington Tops NP, 32°6.9'S 151°25.5'E, 980 m, 11 Feb 1982, WFP (many, AMS C306331); Currys Springs, on Oberon Rd, c. 2 km from Kanangra Walls Rd, Kanangra Boyd Plateau, 33°50.1'S 149°58.2'E, on leaves etc., 11 Dec 1979, WFP & J. Stanisic (many, AMS C353950); Clarence, off Bells Line of Road, small boggy swamp, 33°29'S 151°14'E, swamp, 21 Jun 1990, GAC (8, AMS C361973); Terrace Ck, Jenden SF, 33°36.5'S 150°2'E, 21 Apr 1984, WFP (many, AMS C353942); Middle of Terrace Ck, N of Jenolan Caves, Blue Mountains NP, 33°46.5'S 150°0.2'E, small flowing creek and drain by road, 21 Apr 1984, WFP (many, AMS C351556); stn 25, Stockyard Ck, 150 m SE of Terrace Ck, tributary of Jenolan River, off 4WD track, N of Jenolan Caves, 33°46.6'S 150°0.3'E, in watercress and roots of willows, 13 Dec 1979, WFP (4, AMS C361965); stn RI-7, Imperial Cave Resurgence, Jenolan Caves, 33°49.2'S 150°1.8'E, 19 Apr 1993, S. Eberhard (1, AMS C361944); stn NSW487, eastern headwaters, Council Ck, near Kanangra-Boyd NP, 33°50.51'S 150°0.8'E, 1180 m, *Sphagnum* and gelatinous algae on gravelly substrate, 19 Nov 1992, G. Wilson & party (several, AMS C307132); stn NSW486, spring-fed bog near Luthers Ck, Kanangra-Boyd NP, 33°52.82'S 150°2.62'E, 1225 m, *Sphagnum* and gelatinous algae over silt, 11 Nov 1992, G. Wilson & party (several, AMS C307131); Boyd Plateau, spring into creek, 33°53'S 150°2.67'E, Oct 1988, WFP (many, AMS C361968); stn NSW485, Mumbedah Swamps, Kanangra-Boyd NP, 33°53.76'S 150°3.92'E, 1200 m, *Sphagnum* amongst clumps of sedge, 18 Nov 1992, G. Wilson & party (several, AMS C307129); stn NSW484, Belarah Swamp, Kanangra-Boyd NP, 33°54.31'S 150°4.65'E, 1185 m, *Sphagnum*, sticks and roots submerged in stream, 18 Nov 1992, G. Wilson & party (several, AMS C307127); stn NSW483, Oldmeadow Swamp, Box Ck tributary, off Kowmung River Fire Trail, Kanangra-Boyd NP, 33°56.5'S 150°2.6'E, 1245 m, *Sphagnum* and mixed water plants in spring-fed water, 18 Nov 1992, G. Wilson & party (several, AMS C307125); Small boggy creek, upper Little Morong Creek, Boyd Plateau, Blue Mountains, 33°56.5'S 150°3'E, 21 Apr 1984, WFP (many, AMS C361952); stn NSW482, Boyd Hill

Swamp, Kanangra-Boyd NP, 33°56.97'S 150°1.44'E, 1225 m, downstream from clumps of *Sphagnum* and sedge, 18 Nov 1992, G. Wilson & party (several, AMS C307124); stn NSW481, Boyd Hill Swamp, Kanangra-Boyd NP, 33°57.05'S 150°1.49'E, 1230 m, small aquatic plants in 10cm deep freshwater pool, 18 Nov 1992, G. Wilson & party (several, AMS C307123); stn NSW477, Roly Whalans Swamp, Morong Ck tributary, off Kanangra Rd, Kanangra-Boyd NP, 33°58.55'S 150°3.3'E, 1180 m, *Sphagnum* moss and mixed aquatic vegetation, 17 Nov 1992, G. Wilson & party (several, AMS C307112); stn NSW478, Jensens Swamp, Kanangra-Boyd NP, 33°58.65'S 150°2.76'E, 1175 m, *Sphagnum* moss and mixed aquatic vegetation, 17 Nov 1992, G. Wilson & party (several, AMS C307114); stn NSW479, Jensens Swamp, Morong Ck tributary, 1 km along track off Kanangra Rd, Kanangra-Boyd NP, 33°58.59'S 150°2.78'E, 1175 m, *Sphagnum* moss and mixed aquatic vegetation, 17 Nov 1992, G. Wilson and party (several, AMS C307119); stn NSW480, Dingo Swamp, Kanangra-Boyd NP, 33°59.52'S 150°2.31'E, 1180 m, mixed sedge, *Sphagnum* and swordgrass, 17 Nov 1992, G. Wilson & party (several, AMS C307122); stn WC7-94, Wombeyan Caves, Gap Ck, below Wombeyan Quarry, 34°19.05'S 149°57.61'E, 13 Mar 1994, WFP & GAC (1, AMS C201662); stn WC6-94, small spring on Gap Ck, below Wombeyan Quarry, Wombeyan Caves, 34°18.5'S 150°5.5'E, 13 Mar 1994, WFP & GAC (many, AMS C201675); stn WC5-94, tributary of Wollondilly River, Mares Forest Ck, Wombeyan Caves, 34°18.72'S 150°5.07'E, small spring, 12 Mar 1994, WFP & GAC (many, AMS C201682); N of Mittagong, Nattai E, at "The Crags", 34°23.62'S 150°25.37'E, 25 Apr 1994, WFP & GAC (1, AMS C204163); stn CP3-3, Murray Cave, Cooleman Plain, Kosciusko NP, 35°34.8'S 148°40.2'E, 20 Jan 1994, S. Eberhard (7, AMS C362922); stn 7, Kosciusko NP, Yarrangobilly Caves, River Cave (Y-27), 35°43.5'S 148°29.5'E, in stream gravel, 31 Oct 1980, WFP & JH (1, AMS C353946); same loc., underground stream gravel, 3 Jun 1980, K. Keck (2, AMS C362936); stn 16, Black Walters Ck, Snowy Mountains Hwy, Kosciusko NP, 35°53'S 148°32'E, side creek in roots and algae, 1 Nov 1980, WFP & JH (6, AMS C351557); stn 18, Alpine Ck, on Snowy Mountains Hwy, 8.3 km W from Providence Portal, N Lake Eucumbene, Kosciusko NP, 35°55.5'S 148°35.5'E, in side ditch, 5–8cm water, filled with grass and some algae, 1 Nov 1980, WFP & JH (3, AMS C350016; 5, AMS C353941); stn 52, Yandyguinula Ck ford, 100 m NE of Rossi-Harolds Cross Rd, on fire trail, Tallaganda SF, W of Braidwood, 35°31.5'S 149°32.1'E, 880 m, small sandy slightly stagnant creek, in dead leaves in mud in pools, 16 Jan 1981, WFP & WFPj (3, AMS C350012); stn 57, Round Mt Ck tributary, on Crow Valley Rd, 2 km S of Captains Flat-Ballalaba Rd, Tallaganda SF, SE of Braidwood, 35°38.8'S 149°31.4'E, 950 m, on weed amongst roots in small clean swift creek with sand, 16 Jan 1981, WFP & WFPj (3, AMS C350014; 12 AMS C353944); stn 59, same loc., date & coll., on weed in gentle seepage with mud (5, AMS C361987); stn 71, Reedy Ck ford, Moodong Ck tributary, Deua River tributary, on Bettowynd Fire Trail, Bendoura Ra., 35°43'S 149°41.48'E, 705 m, sedge in creek in narrow clearing in bush, 17 Jan 1981, WFP & WFPj (7, AMS C362000); stn 64, Little Crow Valley Ck tributary, on Crow Valley Creek Rd, Tallaganda SF, 35°44.16'S 149°32.33'E, 1025 m, flowing creek, sand and pebbles, 16 Jan 1981, WFP & WFPj (1, AMS C361996); Blue Lake, Mt Kosciusko, 36°24.2'S 148°19'E, 10 Feb 1977, 4 m deep, B.V. Timms (1, AMS C362925); Club Lake, Mt Kosciusko, 36°25'S 148°17.5'E, 8 Dec 1997, B.V. Timms (many, AMS C347413); Lake Albina at S end, Snowy Mountains, 36°26'S 148°17'E, 8 Feb 1977, 2 m deep, B.V. Timms (9, AMS C362929); same loc. & coll., 9 Feb 1977 (1, AMS C362928); Marble Ck, near junction of Pilot Ck and Murray River, 36°47.15'S 148°11.2'E, 11 Nov 1986, JHW (19, AMS C353948); stn 91, Deep Ck bridge, 800 m S of piggery, on lower Cadgee-Nerrigundah Rd, just above Gluf Ck, Tuross River tributary, 36°8.35'S 149°54.65'E, pools in very small side creek amongst sedge roots, 19 Jan 1981, 30, WFP & WFPj (10, AMS C362914); stn CO27, tributary of Tuross River, on Tuross Falls Rd, Badja SF, 7 km from Countgany Badja Rd, 36°12'S 149°31'E, 1000 m, 5 Nov 1990, GAC (many, AMS C353943); stn 75/7–41, Snowy Mountains Hwy, 4 km E of Steeple Flat turnoff (Tomahawk Ck?), 36°37.25'S 149°23.9'E, small, fast flowing creek, 17 Apr 1975 (1, MV F54912); stn 418E, tributary of Little Bog Ck, on Old Mill Rd, 37°9.88'S 149°5.88'E, 840 m, roots of moss and other vegetation on leaves, 22 Feb 1983, WFP & JH (many, AMS C361979). VICTORIA: stn EV3, Circular Ck. tributary, 100 m upstream from junction of Granite Ck Rd with Circular Ck Rd, N of Myrtleford, 36°26.93'S 146°47.4'E, 660 m, seepage at head of stream, 6 Dec 1988, JHW & GAC (many, AMS C350011; many, AMS C353947); stn EV8, creek, flowing into Buffalo Lake, S of Myrtleford, 36°43.23'S 146°38.67'E, 280 m, in tree fern roots, 7 Dec 1988, JHW & GAC (several, AMS C201853); Near Tatra Inn (Hotel), Mt Buffalo NP, 36°45'S 146°48'E, 4 Jan 1978, BJS (9, MV F54910); Dingo Dell, Mt Buffalo NP, 36°45'S 146°48'E, 15 Dec 1979, BJS (many, MV F54898; many, MV F54878); same loc. & coll., Acid Creek, 1 Jan 1978 (many, MV F54890); same loc. & coll., in plant debris in bog, 18 Apr 1981 (many, MV F54876); same loc. & date, *Sphagnum* bog, in silt, A. Oates & C. Hogarth (many, MV F54882); stn TA2, 19 km NE of Nillahcootie Dam, small spring at top of Watchbox Ck on Loombah Weir Rd., 36°46'S 146°11.6'E, 620 m, swamp at head of spring, very slow flow, algae and water cress plants, 20 Jan 1987, WFP JHW & GAC (10, AMS C362953); Small stream 2 km NE of junction between Native Cat Track and Nunniong Track, c. 25 km E of Benambra, 36°59'S 147°59.5'E, fast flowing stream, under leaves and bark, in silt and debris, 30 Dec 1976, R. Plant (12, MV F54911); stn VIC38, tributary of Loddon River, 1.3 km along road to Lyonville Mineral Springs, Wombat SF, E of Daylesford, 37°22.383'S 144°15.817'E, on roots, weeds and leaves, 20 Feb 1994, GAC & ACM (10, AMS C302500); stn VIC39, small tributary of Riddle Ck, corner of Cherokee-Kerrie Rd, Cherokee, E of Mt Macedon, 37°23.417'S 144°38.217'E, in roots, 20 Feb 1994, GAC & ACM (1, AMS C302492); Lerderderg River, 3.8 km WNW of Blackwood, 37°27.5'S 144°16'E, 23 May 1984, A.J. Boulton (7, MV F54896); Fireplace Ford, Lerderderg River, 3.8 km WNW of Blackwood, 37°27.5'S 144°16'E, 16 Aug 1983, A.J. Boulton (8, MV F52152); stn EV12, Tin Ck, tributary of Acheron River, near Buxton, 37°25.15'S 145°40.183'E, 320 m, in short turf-like weed at edges, 8 Dec 1988, JHW & GAC (many, AMS C362948); Acheron River, E of Healesville, 37°30'S 145°41'E, 11 Feb 1988, I. Doeg (4, MV F54892); summit of Lake Mount, 37°30'S 145°53'E, *Sphagnum* bogs, 30 Oct 1980, BJS & party (many, MV F54897); Echo Flat, summit of Lake Mountain, 37°30'S 145°53'E, bog, 15 Feb 1983, BJS & party (many, MV F54908); Lake Mountain, 37°30'S 145°53'E, bog, 24 Jan 1982, BJS (7, MV F54875); same loc., *Sphagnum* bog covered in snow and ice, 31 Jul 1981, BJS & R. Plant (many, MV F54885); same loc., *Sphagnum* bog, deep layers, 6 Mar 1982, BJS (many, MV F54883); same loc. and coll., *Sphagnum* bog, 26 Jun 1980 (many, MV F54877), 20 Mar 1980 (many, MV F54879), 24 Jan 1980 (many, MV F54880), 16 Dec 1979 (many, MV F54881), 2 Dec 1979 (many, MV F54884); stn EV13, tributary of Maroondah River, tributary of Acheron River, 37°32.68'S 145°40.13'E, 360 m, seepage at head of stream, very slow flow, duckweed and sedges, GAC (many, AMS C362966); Running Creek, Kinglake, 37°34'S 145°13'E, Oct 1977, A. Fletcher (3 decalcified, MV F54901); same loc. & coll., Jul 1977 (1, MV F54900; 1, MV F54902; 1 decalcified fragment, MV F54917; 1, MV F54915); same loc. & coll. (1, MV F54899); same loc. & coll., 3 Apr 1977 (1, MV F54919; 1 decalcified, MV F54918); Acheron River, 13 km E of Healesville, 37°38'S 145°43'E, 22 Feb 1975, L. Macmillon (2 decalcified, MV F54914); same loc., Jul, 1975, BJS & party (MV F29973); Acheron River, 18 km E of Healesville, 37°39.5'S 145°44'E, Jun 1970, L. Macmillon (2, MV F54894); same loc. & coll., 23 Feb 1975 (1, MV F54321); stn TA17, small creek, 1.4 km out of Warburton on Mt Donno Buang Rd, 37°44.883'S 145°42.3'E, 280 m, in dead leaves on edges of steam, 21 Jan 1987, WFP JHW & GAC (9, AMS C362950); stn EV14, Tomahawk Ck, S of Warburton, 37°54.183'S 145°34.133'E, 200 m, flooding, 9 Dec 1988, JHW & GAC (8, AMS C362944); stn EV11, tributary of Delatite River, on road to Mt Stirling, 37°6.52'S 146°26.2'E, 740 m, in leaf litter and debris of flooded stream, 8 Dec 1988, JHW & GAC (1, AMS C362969); stn EV10, tributary of Delatite River, on Mt Buller Rd, 37°6.65'S 146°23.333'E, 600 m, on leaves and roots of ferns, 8 Dec 1988, JHW & GAC (many, AMS C350008; 16, AMS C353949); stn EV9, tributary of Timbertop Ck, near Merrijig, 37°7.3'S 146°16.85'E, 450 m, under rocks and in weed, 8 Dec 1988, JHW & GAC (2, AMS C362960); stn TA11, 49 km S of Mansfield, 1.6 km N of A1 Mine Settlement, 1.4 km S of Goffneys Ck, tributary of Raspberry Ck, 37°30.483'S 146°11.983'E, 640 m, small stream, on and under duckweed, on surface of water, 20 Jan 1987, WFP JHW & GAC (many, AMS C362957); Mt Baw Baw, 37°50'S 146°17'E, running bog, 27 May 1976, J. McAuley (14, MV F54893); same loc., *Sphagnum* bog, on liverworts in free water, 30 Aug 1976, J. McAuley (many, MV F54891); stn VIC49, Boundary Ck, at road crossing, S of Wulgulmerang, 37°7.54'S 148°14.07'E, 900 m, 22 Feb 1994, GAC & ACM (many, AMS C302511); stn EV317, Bonang River tributary, 5 km N of junction with Gap Rd, on Bonang Hwy, 37°12.67'S 148°44.5'E, 820 m, 21 Feb 1990, WFP DLB & RdK (18, AMS C350009); 420 m E, Craigie Bog Ck, on Bendock Rd, off Coast Range Rd, 37°13.08'S 149°3.35'E, 910 m, small pool in creek bed, 22 Feb 1983, WFP & JH (4, AMS C362973); stn VIC5, upper tributary of

Fiery Ck, c. 8 km NW of Raglan on road to Warrak, 37°20.117'S 143°16.917'E, in leaves, roots, 15 Feb 1994, GAC & ACM (12, AMS C302377); stn EV303, 10 Mile Ck, at Cape Liptrap, near Waratah Bay, 38°49.33'S 145°56.2'E, 16 Feb 1990, WFP & RdK (many, AMS C351555); TA 147, tributary of Turtons Ck on Boolarra–Foster Rd (6.2 km N of intersection with Turtons Ck Rd), 38°33.783'S 146°14.5'E, 380 m, under and on leaves, 9 Feb 1987, WFP & GAC (many, AMS C353945); Traralgon Ck, on Traralgon Ck Rd, 38°29'S 146°26'E, 26 Feb 1974, WFP & GAC (1, AMS C362964).

Material identified as G. hedleyi *by B.J. Smith but now decalcified and unidentifiable*. VICTORIA: Bogong High Plains, 36°54'S 147°16'E, Feb 1978, A. Fletcher (2, MV F54920); Toorongo River, 3 km N of Toorongo Rd, 37°51.8'S 146°2.4'E, swamp, Dec 1978 (1, MV F54913); Latrobe River, 9.8 km W of Noojee, 37°53.4'S 145°54.1'E, 14 Aug 1979 (6, MV F54895); Acheron River (see above); Buffalo Ck, Mt Buffalo, 36°43.5'S 146°46'E, Apr 1978, A. Fletcher (3, MV F54922); Running Creek, Kinglake (3 lots—see above); Masons Falls, Kinglake NP, 37°30'S 145°15'E, 20 Oct 1976, A. Neboiss (1, MV F54889).

Diagnosis. Shell with rounded whorls, rarely with weak mid-dorsal angulation; sculpture of fine growth lines only. Protoconch microsculpture of pustules in initial part, remainder smooth. Radula with anterior articulatory thickenings of central teeth larger than posterior; lateral elements well spaced.

Description. Shell (Figs. 1, 2A–F) small (usually up to 2 mm in max. diameter, rarely up to 2.8 mm), orthostrophic, near planispiral, of up to 2.8 typically evenly convex whorls (in a few populations whorls weakly angulate mid dorsally—Fig. 1G,J). Protoconch (Fig. 2A–F) of 1.1–1.3 whorls, divided into an initial portion of about 0.6–0.8 whorls sculptured with distinct pustules and divided off from remainder of protoconch by distinct demarcation; remainder of protoconch with simple growth lines and, in some specimens, a few irregular, low axial ribs. Teleoconch sculpture of fine axial growth lines. Dorsal surface of whorls typically evenly convex but weak dorsal subangulation in some specimens (e.g., Tuross River and Yandyguinula Ck); inclined near suture forming moderately deep sutural excavation; periphery of last whorl evenly convex; ventral surface of last whorl evenly convex. Base with whorls evenly convex, with broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.56–0.67 (mean 0.61, n = 10). Aperture typically slightly pyriform, narrower above where it folds slightly inwards over parietal wall; rarely subcircular (examined using SEM from AMS C350016 [5], AMS C350008 [5], AMS C350009 [4], AMS C350014 [4], AMS C350011 [5], AMS C350012 [4], AMS C350018 [6], AMS C353942 & AMS C351556 [14]). Colour yellowish-white to pale yellow-brown.

Dimensions. See Table 1.

Operculum (Ponder, 1986, fig. 1F,G; Fig. 3A–F,I) subcircular (width/length mean 0.83 [n = 20], range 0.76–0.92; mean of Terrace Creek specimens [n = 8] 0.81, range 0.76–0.86), flat to very slightly concave, of 3.5–3.8 (mean 3.7, n = 11) whorls (1.5–1.8 adult), width of last whorl/length of operculum 0.22–0.37 (mean 0.29, n = 12). Nucleus large, 0.33–0.40 (mean 0.38, n = 12) length of operculum, subcentral to eccentric, spiral (of about 2 whorls), with moderately raised ridge for about 0.5–1.5 whorls on nucleus on inner surface. Exterior with about 10–25 rather irregular rows of spirally arranged pustules on last whorl (examined using SEM AMS C350016 [2], AMS C350008 [2], AMS C350009 [2], AMS C350014 [2], AMS C350011 [2], AMS C350012 [1], AMS C350018 [2], AMS C353942 & AMS C351556 [8]).

Radula (Meier-Brook & Smith, 1976, figs. 9–11; Ponder, 1986, fig. 8a–e; Fig. 4A–E) of 25 rows (Meier-Brook & Smith, 1976; Ponder, 1986). Central teeth with 7–9 (usually

Table 1. Shell measurements of *Glacidorbis hedleyi*.

dmin	dmax	mdht	mxht	aph	apw	whl
lectotype						
1.23	1.48					2.20
paralectotypes						
0.99	1.24	0.35	0.54	0.59	0.47	2.20
1.10	1.33	0.39	0.57	0.60	0.46	2.20
0.87	1.10	0.33	0.47	0.53	0.45	2.00
1.08	1.31	0.37	0.55	0.59	0.49	2.10
0.93	1.15	0.34	0.50	0.56	0.47	1.85
1.13	1.39	0.34	0.53	0.54	0.47	1.85
1.12	1.36	0.37	0.54	0.57	0.47	2.20
1.06	1.35	0.37	0.60	0.49	0.47	2.25
1.02	1.25	0.37	0.51	0.51	0.48	2.10
1.05	1.27	0.34	0.54	0.58	0.47	2.00
figured specimens (AMS C350008)						
1.49	1.74	0.47	0.82	0.79	0.63	2.25
1.62	2.00	0.56	0.83	0.79	0.73	2.65
1.28	1.58	0.46	0.77	0.70	0.63	2.25
figured specimens (AMS C350009)						
2.29	2.85	0.76	1.03	1.00	0.91	2.80
1.91	2.27	0.66	1.13	0.89	0.82	2.75
1.73	2.12	0.54	0.94	0.92	0.79	2.40
figured specimens (AMS C350011)						
1.55	2.02	0.48	0.87	0.77	0.72	2.35
1.50	1.84	0.49	0.80	0.75	0.62	–
1.25	1.60	0.39	0.73	0.65	0.58	2.15
figured specimens (AMS C350012)						
1.51	1.85	0.55	0.77	0.75	0.63	2.45
1.63	1.90	0.58	0.85	0.85	0.65	2.50
1.60	1.88	0.54	0.79	0.79	0.62	2.40
figured specimens (AMS C140426)						
1.84	2.18	0.59	0.83	0.82	0.74	3.00
1.66	2.03	0.55	0.80	0.81	0.68	2.55
1.69	2.03	0.58	0.83	0.80	0.72	2.40
figured specimens (AMS C350016, Alpine Creek)						
1.25	1.55	0.42	0.69	0.68	0.59	2.25
0.96	1.19	0.34	0.60	0.58	0.45	2.00
1.15	1.38	0.39	0.68	0.66	0.55	1.95
figured specimens (AMS C350018)						
1.58	2.00	0.57	0.90	0.88	0.74	2.25
1.61	2.04	0.51	0.83	0.82	0.75	2.20
1.58	1.97	0.52	0.86	0.81	0.77	2.30
1.64	2.07	0.58	0.86	0.84	0.76	2.30

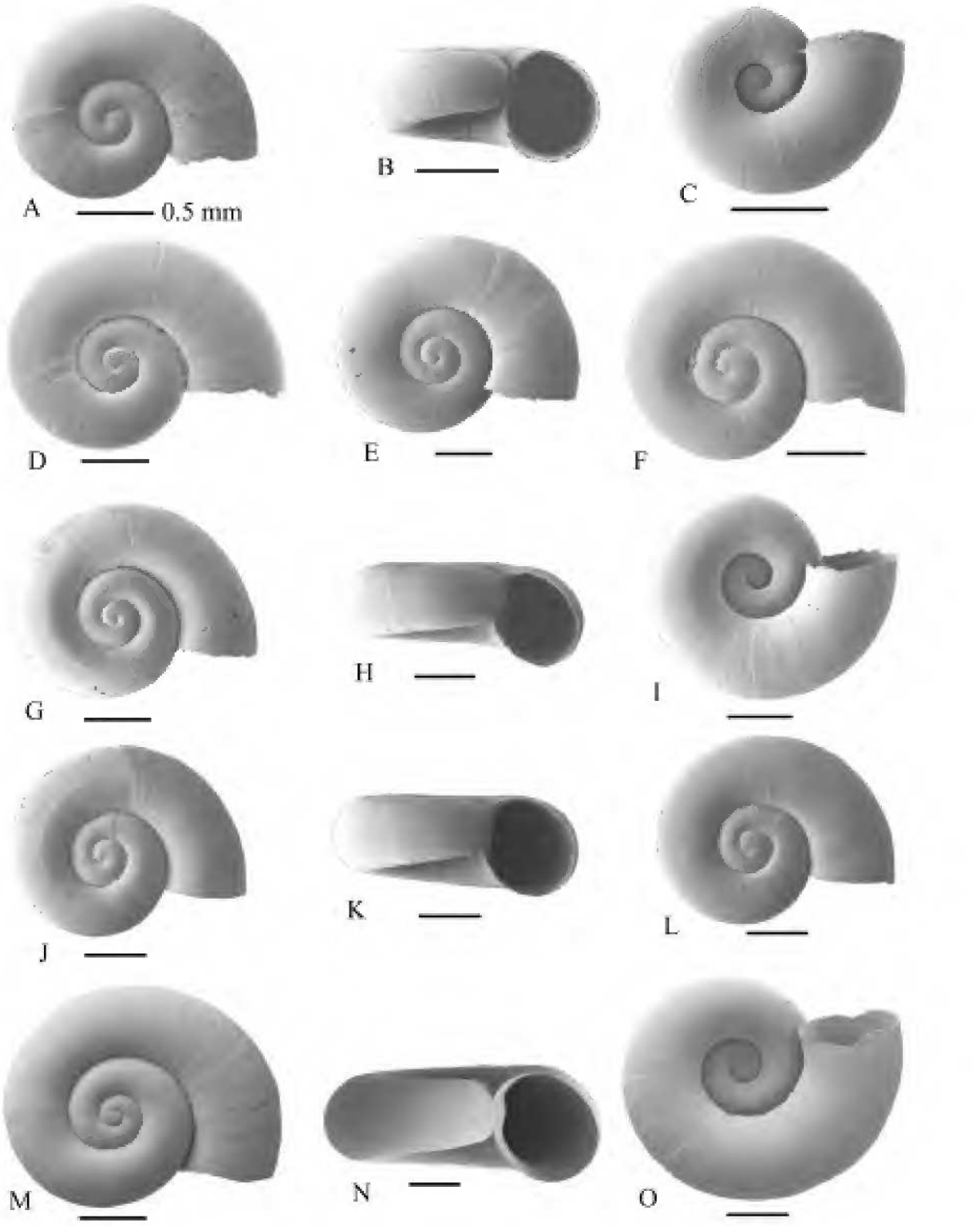


Figure 1. Shells of *Glacidorbis hedleyi*. A–C: Alpine Ck, on Snowy Mountains Hwy, Kosciuszko NP, NSW (AMS C350016); dorsal, lateral and ventral views of three specimens. D: Circular Ck, N of Myrtleford, Victoria (AMS C350011). Dorsal view. E,H: Dawson Spring, Mt Kaputar, NSW (AMS C140426); dorsal and lateral views of two specimens. F: tributary of Delatite River, on Mt Buller Rd, Victoria (AMS C350008); dorsal view. G,I: Yandyguinula Ck, Tallaganda SF, W of Braidwood, NSW (AMS C350012); dorsal and ventral views of two specimens. J–L: tributary of Tuross River, on Tuross Falls Rd, Badja SF, NSW (AMS C350018). Two dorsal and one lateral view of three specimens. M–O: tributary of Bonang River, on Bonang Hwy, Victoria (AMS C350009); dorsal, lateral and ventral view of three specimens.

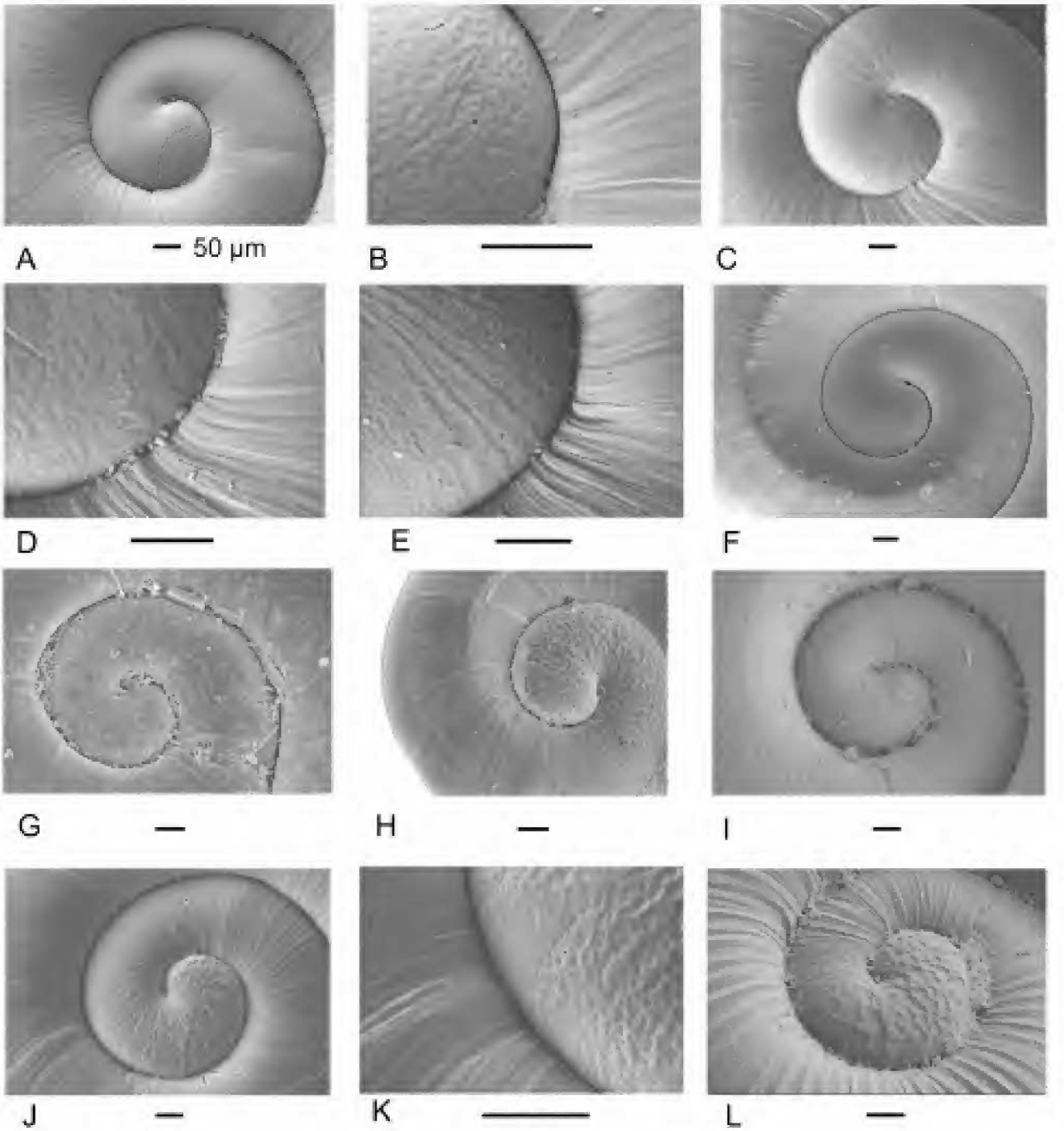


Figure 2. Protoconchs of *Glacidorbis*. A–E: *Glacidorbis hedleyi*. A,B: tributary of Bonang River, on Bonang Hwy, Victoria (AMS C350009); detail of microsculpture (B). C,D: tributary of Tuross River, on Tuross Falls Rd, Badja SF, NSW (AMS C350018); detail of microsculpture (D). E: Alpine Ck, on Snowy Mountains Hwy, Kosciuszko NP, NSW (AMS C350016). F: *Glacidorbis isolatus* n.sp., holotype (AMS C351676). G: *Glacidorbis occidentalis*; Munyerring Brook, NE of Perth, WA (1, AMS C365202). H: *Glacidorbis circulus* n.sp.; Marine Ck, tributary of Mersey R, NE of Railton, northern Tasmania (paratype, AMS C363863). I: *Glacidorbis troglodytes* n.sp., holotype (AMS C351666). J,K: *Glacidorbis tasmanicus* n.sp., tributary of Split Rock Ck, 2.8 km NE of Liawenee on Lake Hwy, Tasmania (paratype, AMS C350049); detail of microsculpture (K). L: *Glacidorbis costatus* n.sp., holotype (AMS C351684).

8) sharp, approximately equal-sized lateral cusps occupying about ⅔ length of mesocone. Base 1.8 wider than long and 1.3 wider than width of mesocone, outer edges straight, dorsal basal thickening moderately developed, anterior articulatory thickening strong, about twice size of posterior, anterior articulation abuts tooth in front, very slightly overlapping. Lateral elements slightly shorter than width of central teeth; width of lateral elements about 0.4 length, slightly wider laterally, with only trace of thickening on inner ends; spacing varies from about equal to about ⅓ width

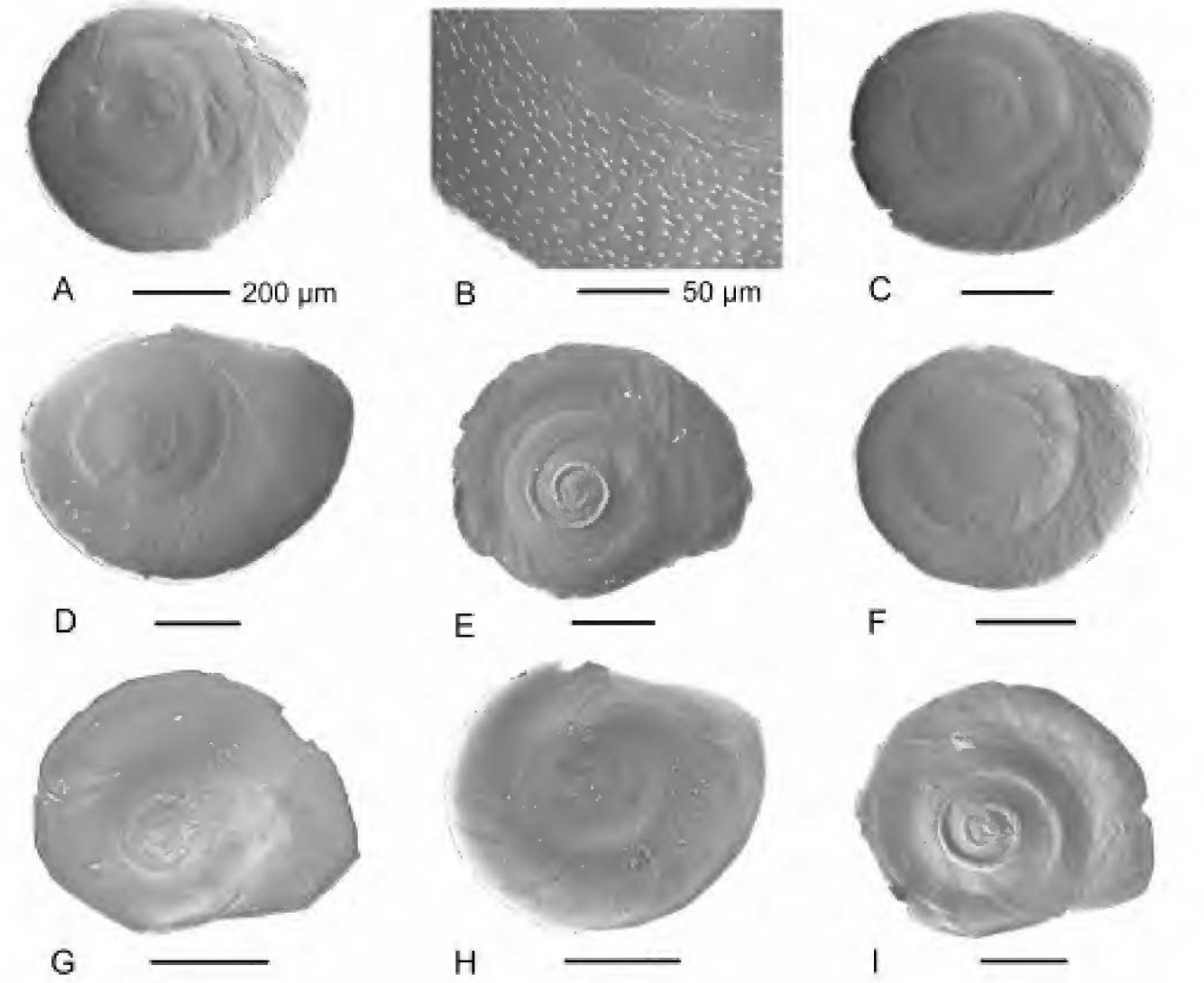


Figure 3. Opercula of *Glacidorbis* species. A–F,I: *Glacidorbis hedleyi*. A,B: Alpine Ck, on Snowy Mountains Hwy, Kosciuszko NP, NSW (AMS C350016); detail of outer surface (B). C: tributary of Round Mountain Creek, Crow Valley Rd, Tallaganda SF, SE of Braidwood, NSW (AMS C350014); outer side. D,E: tributary of Tuross River, on Tuross Falls Rd, Badja SF, NSW (AMS C350018); inner side. F,I: Dawson Spring, Mt Kaputar, NSW (AMS C140426); inner and outer sides. G,H: *Glacidorbis occidentalis*; Canning R., WA (AMS C364665); inner and outer sides. Scale bars for figures A, C–I 200 µm.

of elements and anterior edge finely serrated (description based on Alpine Creek specimens). Paralectotype with 5–7 cusps occupying about ⅔ the length of the mesocone, articulation details appear to be similar to the Alpine Creek specimens. Terrace Creek specimens reported by Ponder (1986) have 5–7 (usually 5 or 6) cusps and the base differs in being slightly wider relative to the mesocone (about 1.5–1.7) and the anterior articulation on the base is slightly more overlapped by the tooth in front. Lateral elements with finely serrated anterior edge, narrowly separated. Specimens from a tributary of Round Mt Creek, NSW, with 5–6 cusps, base of central and lateral elements similar to Alpine Creek specimens with serrated anterior edge. Base mesocone ratio 1.44. Specimens from EV317 with base to mesocone ratio 1.47–1.93, with 6–7 cusps and articulation as in the Alpine Creek specimens. EV3. Radula has 6–9 cusps on the same radula and a base to mesocone ratio of 1.64 and articulation as in the Alpine Creek specimens. Lateral elements larger and with serrated anterior edge. Mt Kaputar specimens (Fig. 4E) with central teeth with 5–7 sharp, approximately equal-sized lateral cusps occupying about ¾ or more of length of mesocone. Base about twice as wide as long, about 1.45–1.72 wider than width of mesocone, outer edges straight, dorsal basal thickening well developed, anterior articulatory thickening stronger than posterior, anterior articulation abuts tooth in front. Lateral elements about as wide as width of central teeth; width of lateral elements about 0.4 length, tapering laterally, with weakly thickened inner ends; anterior edge generally lacking any denticulation, spaced from about ¼ to ½ width apart.

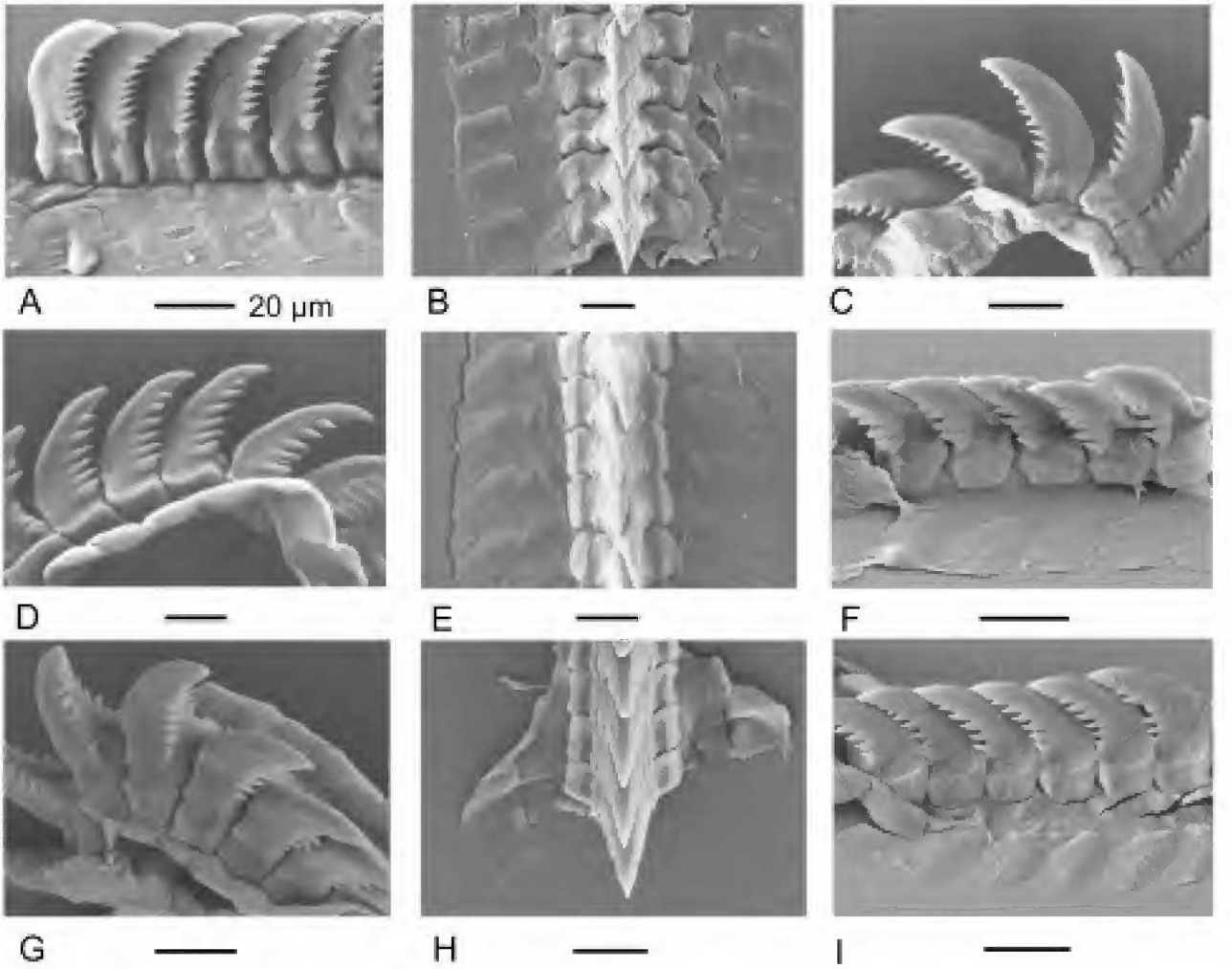


Figure 4. Radulae of *Glacidorbis*. A–E: *Glacidorbis hedleyi*. A,C: Alpine Ck, on Snowy Mountains Hwy, Kosciuszko NP, NSW (AMS C350016); lateral views. B: tributary of Bonang River, on Bonang Hwy, Victoria (AMS C350009); dorsal view. D: tributary of Tuross River, on Tuross Falls Rd, Badja SF, NSW (AMS C350018); lateral view. E: Dawson Spring, Mt Kaputar, NSW (AMS C140426); dorsal view. F: *Glacidorbis occidentalis*; Canning R., WA (AMS C364665). G–I: *Glacidorbis tasmanicus* n.sp. G: tributary of Split Rock Ck, 2.8 km NE of Liawenee on Lake Hwy, Tasmania (paratype, AMS C350049); dorsolateral view. H: McKenzies River on McKenzies Valley Rd, NE Tasmania (AMS C202222); dorsal view. I: tributary of Black Rivulet, NNE of Ringarooma, NE Tasmania (AMS C202223); lateral view.

Ovovivipary was first recorded by Smith (1979) who noted that large, well-developed embryos were present, some up to ¾ of a whorl but gave no further details. Pallial cavity contains up to nine capsules (usually less) and range in size from 0.24–0.45 mm (Ponder, 1986).

Distribution (Fig. 5). Originally described from Blue Lake, Mt Kosciuszko [Kosciusko = old spelling], this species was recorded from additional localities in the Great Dividing Range of Victoria, as far west 143°16'E (near Warrak) and southern NSW (Smith, 1979; Boulton & Smith, 1985). Ponder (1986) extended the range of this species to the Blue Mountains, near Sydney.

Ecology. Found in rivers, streams and bogs, in upland and highland areas, including intermittent rivers (Smith 1978; Boulton & Smith 1985) and streams. Boulton & Smith (1985) note that the average pH was slightly acidic (6.5–6.8) in their study sites in Victoria.

Remarks. The specimens described by Ponder (1986) are indistinguishable from the type series and other material from the Snowy Mountains in all but the radular characters noted above. These differences do not appear to be significant and additional minor variation has been observed in the other populations examined (see above). Some populations (e.g., AMS C350018 and AMS C350012 in south eastern NSW and MV F54897, AMS C353945 and AMS C362973 in Victoria) have the majority of specimens showing a weak basal angulation at the edge of the umbilicus and some have, in addition, a weak dorsal angulation at about the sutural ⅓ of the dorsal part of the whorl. These differences are not clear cut and gradation can be found from normal convex whorls to weak angulation even within

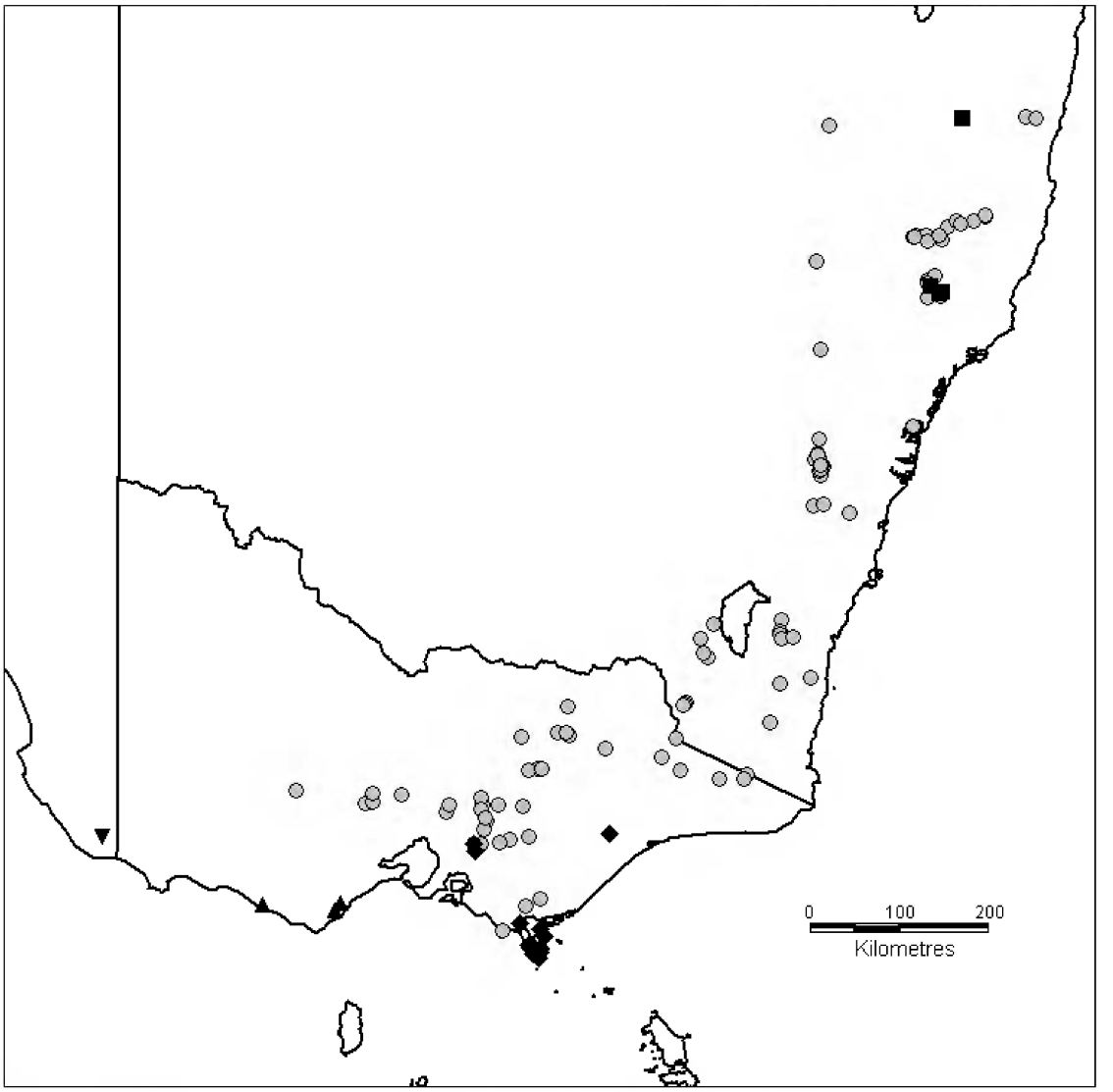


Figure 5. Distribution of *Glacidorbis hedleyi* (circles), *G. isolatus* (■), *G. rusticus* (◆), *G. otwayensis* (▲) and *G. troglodytes* (▼).

one population. In addition, the radular and opercula details show no observable differences.

The isolated Mt Kaputar material is considered to be conspecific because it cannot be separated morphologically from typical material, other than the radula having slightly wider lateral elements.

This species is unusual amongst those included in the genus in having the protoconch demarcated into two sharply divided parts, an initial pustulose portion followed by a smooth part. The former is presumably the initial larval shell and the latter that part of the shell that grows during brooding. While this same configuration is found in a new species described below from New South Wales, it has not been seen in other species. Brooding has not been observed in any other species of *Glacidorbis* and, while brooding cannot be entirely discounted, the less obvious or absent second larval shell seen in the other taxa may support the notion that these have a different reproductive strategy.

Glacidorbis occidentalis Bunn & Stoddart, 1983

Glacidorbis occidentalis Bunn & Stoddart, 1983: 50, figs. 1–7; Bunn *et al*., 1989: 25–34; Smith, 1992: 224.

Type material. HOLOTYPE, WAM 778.82. PARATYPES (5): 3, WAM 779.82; 2, WAM 780.82.

Type locality. Wungong Brook, Jarrahdale, at the Chandler Bridge (32°17'S 116°08'E), WA, S. Bunn, 21 July 1982 (holotype). Paratypes: Dillon Brook, North Dandalup, WA (32°30'S 116°04'E), S. Bunn, 23 July 1982 (WAM 779.82); Seldom Seen Brook, Jarrahdale, WA (32°16'S 116°06'E), S. Bunn, 2 July 1982 (WAM 780.82).

Material examined. WESTERN AUSTRALIA: NOT DECALCIFIED: Munyerring Brook, NE of Perth, 1 Oct 1998, B. Robson, 31°25.1'S 116°11.13'E (2, AMS C365202) (figured specimen). DECALCIFIED: stn

CD1A-4, Kangaroo Gully, Canning River, 32°6'S 116°9'E, intermittent stream, 1 Oct 1985, S. Bunn (7, AMS C362993); stns CD1A-5 & A-8, Kangaroo Gully, Canning River, 32°6'S 116°9'E, intermittent stream, 6 Aug 1985, S. Bunn (13, AMS C364665; 16, AMS C363001); stns LC 2 & 3, Araluen Rd, Canning River, 32°9'S 116°7'E, intermittent stream, 5 Jul 1985, S. Bunn (14, AMS C362996; 14, AMS C362998); stn 5, Wongung Brook, Jarrahdale, 32°10'S 115°59'E, 2 Jun 1982, S. Bunn (2, MV F54886); same loc. & coll., 31 Aug 1982, S. Bunn (7, MV F54888); stn 10, Dillon Brook, North Dandalup, 32°31'S 116°1'E, 23 Jul 1982, S. Bunn (1, MV F54887).

Diagnosis. Shell minute, with convex whorls and very fine growth lines. Protoconch with microsculpture of minute pustules. Differs from all other species in the very narrow base of the central teeth.

Description. Shell (Figs. 2G, 6G–I) very small (up to 1.2 mm in max. diameter), orthostrophic, near planispiral, of up to 2.6 whorls. Protoconch (based on AMS C365202; Fig. 2G) 1.3 whorls, initial whorl almost smooth, with weak, irregular pitting, last third whorl with traces of what appear to be a few very indistinct spiral threads. Teleoconch sculpture of weak, close growth striae. Dorsal and ventral surfaces of whorls and periphery of last whorl evenly convex. Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.58. Aperture subcircular (2 specimens examined using SEM from AMS C365202). Colour of periostracum light brown.

Dimensions. See Tables 2 and 3.

Operculum (Bunn & Stoddart, 1983: 50, fig. 2; Fig. 3G,H) subcircular (width/length 0.81–0.87), flat, of about 3.5 whorls, width of last whorl/length of operculum 0.89–0.31. Nucleus large, 0.457 length of operculum, subcentral, spiral (of 2.5 whorls), initial whorl small, width relative to opercular width only 0.098. Inner surface with only suggestion of thickened ridge for about 0.5 whorls from nucleus. Exterior with scattered pustules on last whorl, approx. 20 in line from suture to edge (examined from 3 specimens from AMS C364665).

Radula (Bunn & Stoddart, 1983: 50, figs. 3–6; Fig. 4F) of 19–20 rows of teeth. Central teeth with 2–5 sharp, approximately equal-sized lateral cusps occupying about ½ to ⅔ length of mesocone. Base very narrow, only 1.14 wider than long, about 1.2 wider than width of mesocone, outer edges straight, dorsal basal thickening moderately developed, anterior articulatory thickening very prominent, posterior articulatory thickening very weak, anterior articulation slightly overlaps base of tooth in front. Lateral elements abutting, uniformly thin, about 1.5 wider than bases of central teeth, about 1.5 wider than long, not tapering, outer edge straight, anterior edge with few irregular serrations (not finely denticulate as in *G. hedleyi*) (based on Canning R., southern WA, and some details also from Bunn & Stoddart, 1983: 50, figs. 3–5) (3 radulae examined from AMS C364665).

Head-foot. Described and illustrated by Bunn & Stoddart (1983: 50, fig. 7). Similar to *G. hedleyi* but the sketch shows relatively longer cephalic tentacles and a wider snout and anterior foot. The animal varies from cream to dark grey depending on the locality (Bunn & Stoddart, 1983: 50). The animal removed from its shell is unpigmented (preserved material).

Table 2. Shell measurements of type specimens of *Glacidorbis occidentalis* from Bunn & Stoddart, 1983.

dmax	apw	whl
holotype		
0.96	0.44	2.3
paratypes WAM 779.82		
0.84	0.36	2.1
1.08	0.40	2.2
0.68	0.32	1.6
paratype WAM 780.82		
1.20	0.48	2.6

Table 3. Shell measurements of specimens of *Glacidorbis occidentalis*.

dmin	dmax	mdht	mxht	aph	apw	whl
figured specimen (AMS C365202)						
0.51	1.27	0.45	0.33	0.49	0.42	2.2
additional specimen (AMS C365202)						
0.46	1.01	0.38	0.27	0.42	0.35	2.2

Distribution. Bunn & Stoddart (1983) list several localities in close proximity near Jarrahdale when they described this species, but Bunn *et al.* (1989) added considerably more locations that extend from the south side of Perth at about 32°S south along the Darling Escarpment for nearly 60 km (see Bunn *et al.*, 1989, fig. 1).

Remarks. This species is unusual in frequenting intermittent streams in the ranges south of Perth. Its ecology has been described by Bunn & Stoddart (1983) and Bunn *et al.* (1989) and in the latter paper information is given on seasonal occurrence and size structure.

Unfortunately all of the original material that could be located, other than the types, is decalcified. The shell description provided here is based on the original data supplemented by the examination of two shells (Figs. 6G–I) from a locality north-east of Perth, whereas the material included in the original description was from south of Perth. The specimens agree well with the original description, although they are slightly larger than the type series.

Bunn *et al.* (1989) described "brooded young which appear to be released as veligers during the winter months" and that the brood pouch contained 33–218 (mean 106, n = 10) "shelled veligers" 65–83 µm in diameter along the entire length of the pallial cavity while in others the "veligers" were present in only the anterior part (2–34, mean 15, n = 9). The "veligers" were of similar size along the entire length of the brood pouch and are illustrated in Bunn *et al.* (1989, figs. 3 and 4). Examination of their slides has shown that many of the "veligers" are present in the digestive gland or loose in the pallial cavity, as can be seen in their figure 4. They are actually the pollen grains of *Pinus* sp., exotic pine

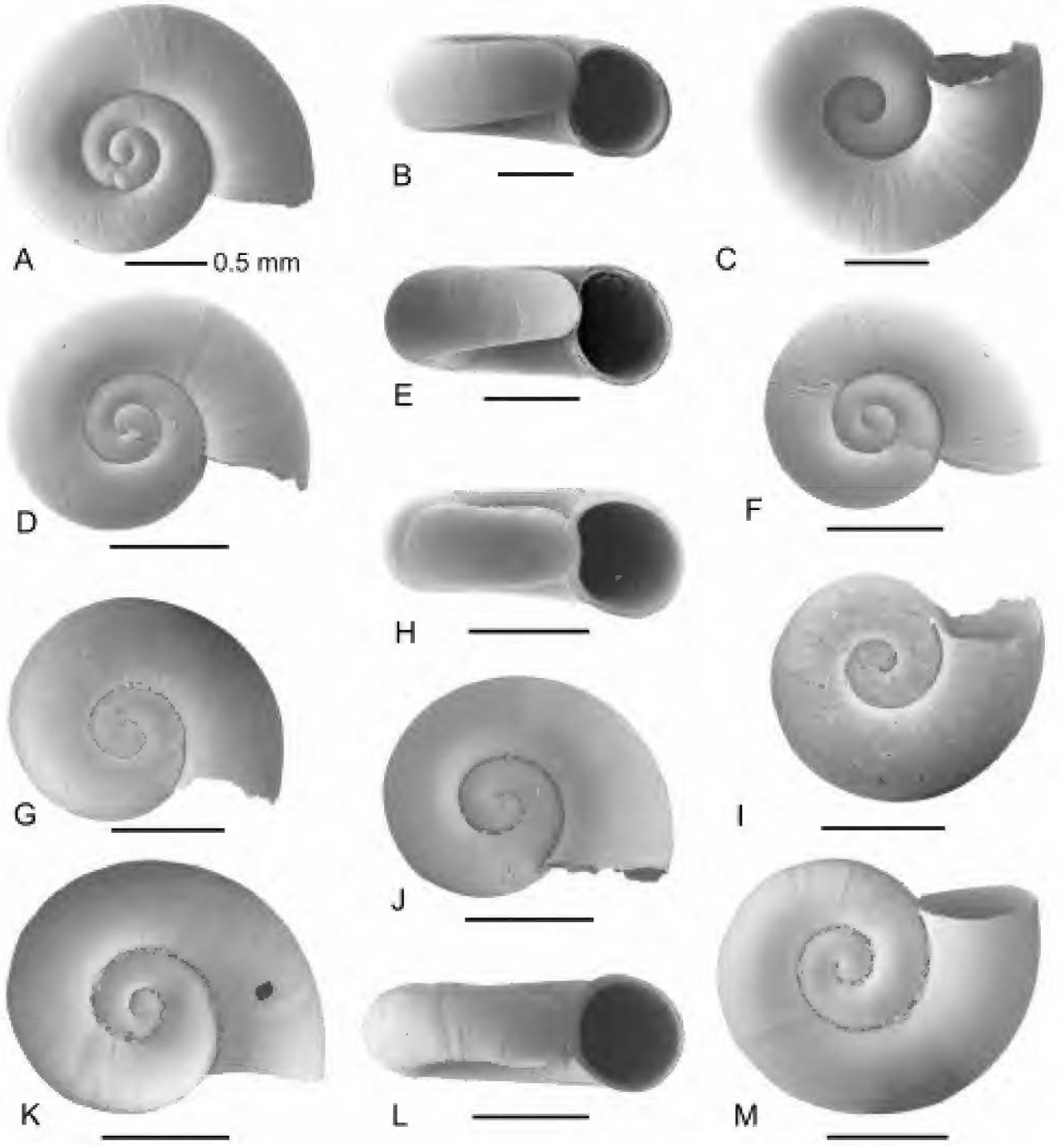


Figure 6. Shells of *Glacidorbis*. A–F: *Glacidorbis tasmanicus* n.sp. A–C: tributary of Split Rock Ck, 2.8 km NE of Liawenee on Lake Hwy, Tasmania; holotype (A) (AMS C351714); paratypes (B,C) (AMS C350049); lateral and ventral views. D: McKenzies River on McKenzies Valley Rd, NE Tasmania (AMS C202222); dorsal view. E,F: tributary of Black Rivulet, NNE of Ringarooma, NE Tasmania (AMS C202223); lateral and dorsal views. G–I: *Glacidorbis occidentalis*; Munyerring Brook, NE of Perth, WA (2, AMS C365202); dorsal, lateral and ventral views of the same specimen. J–M: *Glacidorbis troglodytes* n.sp.; One Tree Sink Hole (= Wurwurlooloo 5L7), near Mt Gambier, South Australia. J: holotype (AMS C351666); dorsal view. K–M: dorsal, lateral and ventral views of a paratype (AMS C350044).

plantations being common in the area. It is not known whether the pollen is ingested selectively or whether it is taken up accidentally while feeding on other material that is not readily detected in the gut.

While the shell, radular and opercular characters are mainly typical of the genus, unusual features include the narrow base of the central teeth of the radula and the very weak (virtually absent) internal thickening on the inner side

of the operculum. The shell is similar to *G. hedleyi* in shape and in lacking any keels or significant sculpture, although differing in its smaller size and more nearly planispiral coiling. It also has a protoconch microsculpture of minute pustules but these are smaller in *G. occidentalis*, being about 3–4 µm in diameter, compared with about 5–7 µm in *G. hedleyi*.

Two decalcified specimens of *Glacidorbis* from south Western Australia has been examined that were found in peatlands near Walpole, southern WA. These are about the same size as *G. occidentalis* but the animal is coarsely spotted with black. Confirmation of their identity must await the examination of better material. The data associated with these specimens is as follows: Yeagarup Lake, southern WA, AMG 50 396766 6177230 P. Horwitz, by net Oct 1993; Poorginup Swamp, southern WA, AMG 50 473745 6176016 in crayfish burrow, P. Horwitz, April, 1993.

Glacidorbis tasmanicus n.sp.

Derivation. Named after Tasmania.

Type material. HOLOTYPE, AMS C351714. PARATYPES: 2, AMS C350049; 6 dry and many wet, AMS C355554; 2, TM E23416; 2, QVM 9:16234.

Type locality. Stn TA130, Tributary of Split Rock Ck, 2.8 km NE of Liawenee on Lake Hwy, Tasmania, 41°52.8'S 146°41.283'E, in sedges, 7 Feb 1987, 1040 m, WFP & GAC, pH 7.26, cond. 0.01.

Additional material examined. TASMANIA: stn TA94, tributary of Ringarooma River on Gladstone Rd 3.3 km S of Gladstone, 40°59'S 148°1'E, 100 m, 30 Jan 1987, WFP JHW & GAC (many, AMS C363834); stn TA81, McKenzies River on McKenzies Valley Rd, 41°16.59'S 147°32.58'E, 300 m, seepages on banks, 28 Jan 1987, WFP JHW & GAC (many, AMS C202222); stn TA70, Pearly Brook, tributary of Great Forester River on Speck Rd, 41°4.6'S 147°39.783'E, 100 m, on tree fern roots and under stones, 27 Jan 1987, WFP JHW & GAC (2, AMS C202217); stn TA71, upper parts of Speck Ck on side road off Speck Rd, 41°4'S 147°40.683'E, 120 m, on dead leaves and tree fern roots, 27 Jan 1987, WFP JHW & GAC (1, AMS C363844); stn TA86, tributary of Black Rivulet, 200 m S of Main Ck, NNE of Ringarooma, 41°13.3'S 147°47.8'E, 500 m, in *Sphagnum* bog near stream, 29 Jan 1987, WFP JHW & GAC (many, AMS C202223); stn TA91, tributary of Frome River, E of crossing of Frame River, on Greenstone Rd, 41°8.5'S 147°53.983'E, 220 m, on leaves, 30 Jan 1987, WFP JHW & GAC (7, AMS C363738); stn TA92, tributary of Frome River on NW side, 0.5 km NE along Greenstone Rd, 41°8.2'S 147°54.183'E, 240 m, under dead leaves in faster part of stream on wood, 30 Jan 1987, WFP JHW & GAC (1, AMS C363908); stn TA101, Carters Ck tributary of Scamander River, 1 km N of Scamander River, Hogans Rd, 41°24'S 148°5.883'E, 100 m, under stones, on dead leaves in flowing water, 31 Jan 1987, WFP JHW & GAC (2, AMS C363841); stn C75T, top end of Ansons River on road between New England Rd and Cliffords Rd, NW of St Helens, 41°11.78'S 148°6.42'E, 140 m, sandy small stream, 17 Jan 1982, WFP JH & WFPj (7, AMS C363902).

Diagnosis. Similar to *G. hedleyi* but differs in having a more coarsely sculptured protoconch, with the sculpture composed of irregular pits and ridges rather than pustules. Teleoconch has a weak or absent ridge in the dorsal sutural third and the operculum has fewer whorls with more numerous pimples than in *G. hedleyi*. The radula has larger, abutting lateral elements and equal-sized articulatory thickenings anteriorly and posteriorly.

Description. Shell (Figs. 2J,K; 6A–F) small (up to 1.9 mm in max. diameter), orthostrophic, near planispiral, of up to about 3.1 convex whorls. Protoconch (Fig. 2J,K) of about 1.2–1.3 whorls, sculptured with rather irregular, distinct shallow pits. Protoconch followed by about ⅓ whorl of possible larval shell not clearly demarcated from teleoconch. Teleoconch sculpture of fine, straight, rather regular, collabral growth lines. Dorsal surface of whorls steeply inclined near suture forming moderately deep sutural excavation; periphery of last whorl evenly convex; ventral surface of last whorl evenly convex. Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.65–0.70. Aperture slightly pyriform, narrower above where it folds inwards over parietal wall (9 examined using SEM, from the type locality [3], AMS C202222 [3] and AMS C202223 [3]). Colour yellowish-white.

Dimensions. See Table 4.

Operculum (Fig. 7I,J) oval (width/length 0.72–0.87, mean = 0.82, n = 5), flat, of c. 3.6 whorls (1.6 adult), width of last whorl/length of operculum 0.28–0.40. Nucleus large, 0.20–0.33 length of operculum, spiral (of about 2 whorls), subcentral. Inner surface with ridge from nucleus occupying half whorl and prominent muscle scar. Exterior with numerous (30–40+) rather irregular rows of partly spirally arranged pustules on last whorl (8 specimens examined, from the type locality [2], AMS C202222 [3] and AMS C202223 [3]).

Radula (Fig. 4G,I) of 17–22 rows. Central teeth with 3–9 (normally 5–6) sharp, approximately equal-sized lateral cusps occupying about ⅔ or a little less length of mesocone. Base 2.5–2.8 (2 in AMS C202223) wider than long, about 1.6–1.9 wider than width of mesocone, outer edges straight, dorsal basal thickening well developed, anterior and posterior articulatory thickenings about equal in strength, anterior articulation abuts tooth in front. Length of lateral elements shorter than width of central teeth; width of lateral elements about twice length, laterally tapering and curved anteriorly, with very weakly thickened inner edge; each element abuts, anterior edge distinctly denticulate (10

Table 4. Shell measurements of *Glacidorbis tasmanicus*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype						
1.64	1.89	0.52	0.85	0.81	0.71	2.60
paratypes (AMS C350049)						
1.51	1.75	0.50	0.77	0.73	0.61	2.50
1.48	1.80	0.53	0.81	0.81	0.63	2.55
figured specimens (AMS C202222)						
1.14	1.39	0.38	0.62	0.61	0.55	2.30
1.31	1.61	0.43	0.69	0.70	0.54	2.60
1.17	1.42	0.39	0.66	0.65	0.52	2.35
figured specimens (AMS C202223)						
0.95	1.19	0.33	0.53	0.50	0.46	2.20
0.80	1.02	0.30	0.51	0.49	0.40	2.00
0.84	1.07	0.30	0.50	0.47	0.37	2.00

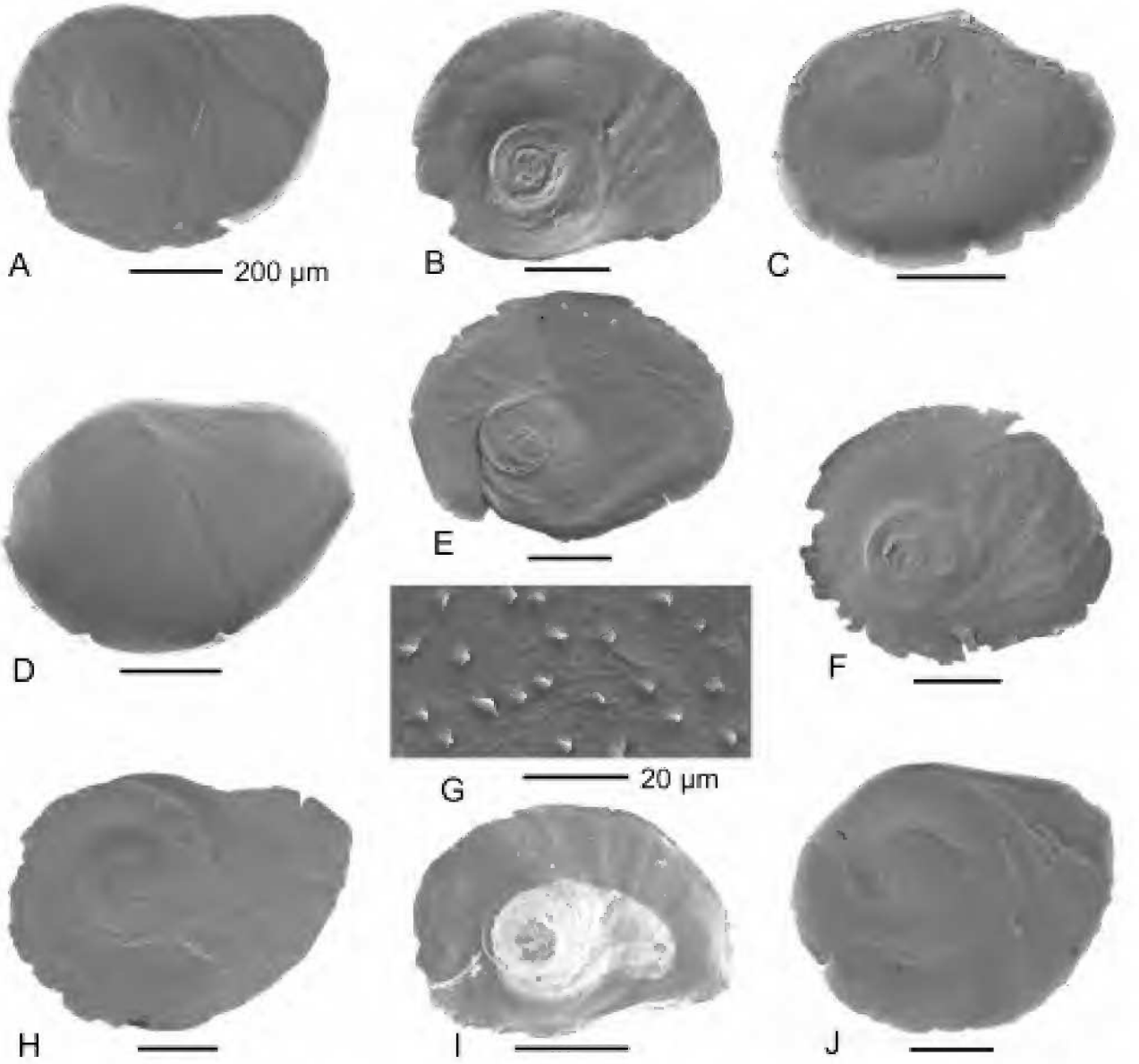


Figure 7. Opercula of *Glacidorbis*. A,B: *Glacidorbis catomus* n.sp.; Hurst Ck, at Oakdene Rd, W of Scottsdale, Tasmania (paratypes, AMS C350050); outer and inner sides. C,F: *Glacidorbis atrophus* n.sp.; tributary of Big Ck, off Tram Rd, S of Wynyard, NW Tasmania (paratype, AMS C202354); outer and inner sides. D,E: *Glacidorbis decoratus* n.sp.; tributary of Mosquito Ck, on Corner Rd, NW Tasmania (AMS C350046); outer and inner sides. G,H: *Glacidorbis rusticus* n.sp.; Squeaky Ck, Wilsons Promontory, Victoria (paratype, AMS C350047); outer side (H); detail of outer surface (G). I,J: *Glacidorbis tasmanicus* n.sp. I: McKenzies River on McKenzies Valley Rd, NE Tasmania (AMS C202222); inner side. J: tributary of Split Rock Ck, 2.8 km NE of Liawenee on Lake Hwy, Tasmania (paratype, AMS C350049); outer side. Scale bars for figures A–F and H–J 200 µm.

specimens examined, from the type locality [4], AMS C202222 [3] and AMS C202223 [3]).

Distribution (Fig. 8). This species is known from several localities in NE Tasmania and one on the Central Plateau.

Remarks. This species is similar to *G. hedleyi* from Victoria and New South Wales in teleoconch and radular characters. It differs in having a strongly pitted protoconch microsculpture, not pustulate, and lacking a distinct secondary larval portion of the protoconch (although there is a suggestion of this in some specimens for about a third of a whorl, it is not clearly defined as in *G. hedleyi*). Unlike *G. hedleyi*, there is no evidence of brooding in *G. tasmanicus*, although relatively few specimens of the latter species have been examined.

Given the disjunct distribution of this species, reduction of keeling in more than one lineage may have resulted in independently similar shell morphologies. Some variation

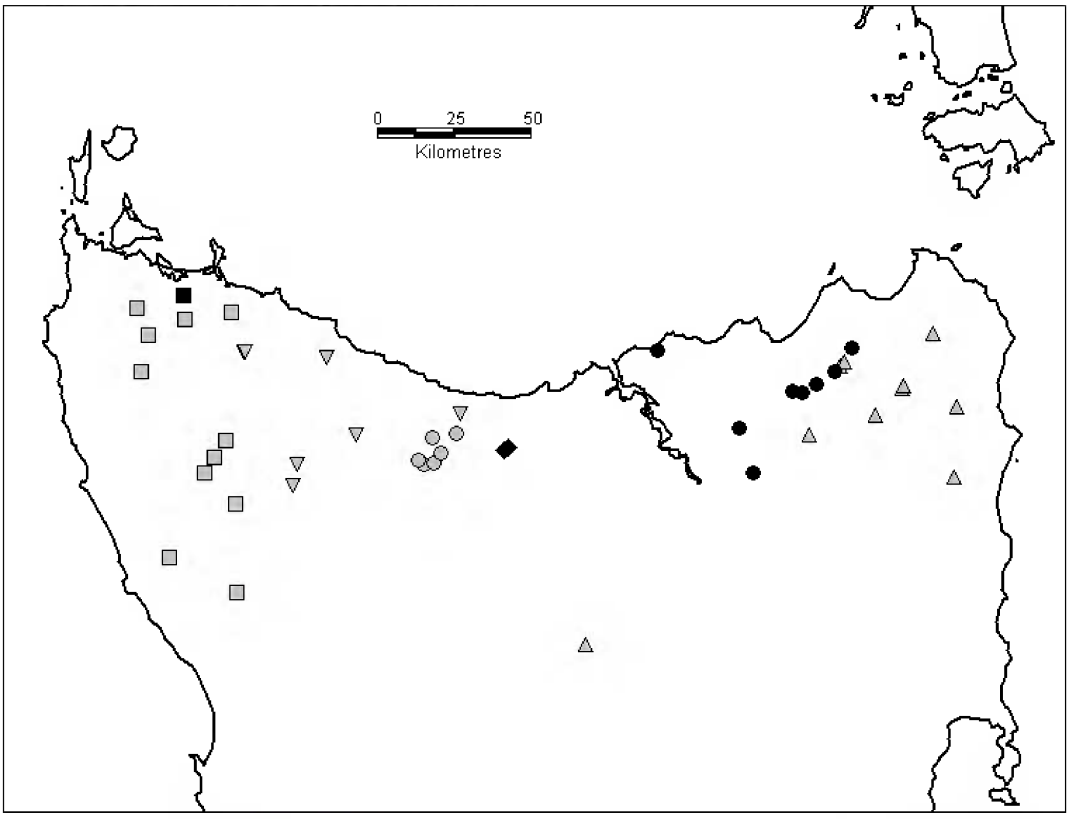


Figure 8. Distribution of *Glacidorbis tasmanicus* (shaded △), *G. costatus* (■), *G. circulus* (◆), *G. decoratus* (shaded □), *G. catomus* (●), *G. atrophus* (shaded ▽) and *G. bicarinatus* (shaded ○).

occurs within the NE; for example specimens from a tributary of Black Rivulet (AMS C202223) are smaller than those in the other two series (see measurements) but the ratios of the shell measurements are similar, as are the details of the radula and operculum. In the absence of distinctive shell microsculpture or other evidence to separate them, all these populations are regarded as conspecific.

The only other almost smooth-shelled species previously described from Tasmania is *G.* pawpela* from Great Lake. One population of *G. tasmanicus* was taken from a stream on the edge of Great Lake but these two species differ, however, in several characters, including size (*G. pawpela* is twice the size, reaching 3.1 mm in maximum diameter compared with 1.6 in *G. tasmanicus*), shell morphology, the whorls more rapidly increasing in width in *G. pawpela* (diameter of last whorl/diameter of shell in *G. pawpela* = 0.41 compared with 0.32–0.38 in the populations attributed to *G. tasmanicus* [0.32 in the Great Lake population]) so that it reaches a greater diameter and has about the same number of whorls. The last whorl is more steeply inclined towards the dorsal suture in *G. pawpela* than in *G. tasmanicus* (cf. Fig. 15A and 6A,D,F). The radula differs considerably in the two species, with *G. pawpela* having 17–18 denticles along most of the edge of the mesocone whereas in *G. tasmanicus* the 3–7 teeth occupy ⅔ or less of the length of the mesocone.

* Placed in *Benthodorbis* below.

Glacidorbis bicarinatus species group

The following six species from northern and NW Tasmania and coastal Victoria typically have a distinctly bicarinate shell, the dorsal (and usually the ventral) carina forming a distinct angulation of the whorl. The protoconch microsculpture consists of pits. These taxa are nearly all allopatric and relatively small, but apparently consistent differences separate them.

Glacidorbis bicarinatus n.sp.

Derivation: *bi* (Latin)—two, *carinatus* (Latin)—keeled.

Type material. HOLOTYPE, AMS C351694. PARATYPES (18): 2, AMS C202347; 5, AMS C354949 (dry); 9, AMS C364669 (wet); 1, QVM 9:1643; 1, TM E23417.

Type locality. Stn TA512B, 3 km E of Preston, West Gawler, Tasmania, 41°17.22'S 146°5.85'E, Roots, moss, liverworts and leaves, 5 Feb 1989, 260, WFP JHW & FEH, pH 6.42, cond. 0.06.

Additional material examined. TASMANIA: Stn C108T, Buttons Rivulet on South Preston Rd, 41°21.117'S 146°2.767'E, 500 m, in weed and under stones, 20 Jan 1982, WFP JH & WFPj (4, AMS C363899); Castra Rivulet, S of Upper Castra, S of Ulverstone, 41°21.62'S 146°6.07'E, treeferns, duckweed, roots, etc., 16 Jan 1992, WFP & JMP (many, AMS C203829);

stn TA506, Upper Castra, Heathcote Ck (trib. of East Gawler R.) on Castra Rd, 41°19.78'S 146°7.93'E, 400 m, on stones, 4 Feb 1989, WFP JHW & FEH (1, AMS C202343); Nietta Ck, S of Ulverstone, tributary of Castra Rivulet, Wilmot River, 41°21.83'S 146°4'E, medium creek, with stony bed, 16 Jan 1992, WFP & JMP (1, AMS C201448); TA 514, top end of Viking Ck, tributary of Wilmot River, 41°16.383'S 146°11.283'E, 220 m, leaves and pieces of small wood, 5 Feb 1989, WFP JHW & FEH (2, AMS C363904); stn TA515B, tributary of Little Clayton's Rivulet, 41°13'S 146°12.28'E, 120 m, on leaves and stones, 5 Feb 1989, WFP JHW & FEH (3, AMS C202485).

Diagnosis. Dorsal carinae strong, raised as strong cord, at about sutural ⅓ to ½, ventral carina strong, in middle of base; microsculpture of weak to moderate costae on first whorl, otherwise weak growth lines and extremely fine spiral threads, latter mostly visible only in transmitted light. Radula with 8–9 cusps and overlapping articulation.

Description. Shell (Figs. 9C,D; 10A–C,E,L) small (up to 1.9 mm in max. diameter), orthostrophic, near planispiral, up to about 2.7 bicarinate whorls. Protoconch (Fig. 9C,D) of about 1.0–1.2 whorls, sculptured with shallow, irregular pits, borders of pits irregular and narrow. Protoconch followed by about ⅓ whorl of possible larval shell not clearly demarcated from teleoconch. Teleoconch microsculpture of fine growth lines, first whorl with weak to moderate costae; prominent raised keel in middle of whorl; base with strong keel on middle of whorl. Dorsal surface of whorls on sutural side of keel strongly sloping into suture; periphery of last whorl evenly convex; outer ventral surface of last whorl convex, inside keel flat and sloping to umbilicus. Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.69. Aperture subcircular (3 specimens examined using SEM from type locality). Colour pale yellow-white to white, opaque to slightly semi-translucent.

Dimensions. See Table 5.

Operculum oval (width /length 0.80–0.84), flat, of c. 3.4 (c. 1.4 adult) whorls; width of last whorl/length of operculum 0.40. Nucleus large, 0.42 length of operculum, spiral (about 2 whorls), eccentric. Inner surface with slightly raised spiral ridge surrounding part of nucleus. Exterior with numerous approximately spirally arranged pustules on last whorl (3 specimens examined from type locality).

Radula (Fig. 11A,B) of 21–22 (n = 3) rows. Central teeth with 8–9 sharp, approximately equal-sized lateral cusps occupying about ¾ length of mesocone. Base wider than long (width/length 0.39–0.42), 1.7 to about twice width of mesocone, outer edges slightly concave to slightly convex, dorsal basal thickening prominent, anterior articulatory thickening stronger than posterior, anterior articulation slightly overlapped by dorsal part of posterior articulatory area of tooth in front. Width of lateral elements about half their length, not tapering, straight to slightly curved, with posterior edge of inner ends weakly thickened; plates abutting to narrowly separated, anterior edges finely denticulate (3 radulae examined from type material).

Table 5. Shell measurements of *Glacidorbis bicarinatus*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype						
1.56	1.88	0.53	0.81	0.75	0.65	2.65
paratypes (AM C202347)						
1.29	1.54	0.49	0.81	0.78	0.58	2.25
1.36	1.59	0.50	0.82	0.75	0.59	2.40

Distribution (Fig. 8). Mid north coast, in tributaries of Gawler River.

Remarks. The material attributed to this species is very constant over the small area it occupies. It is contrasted with the other species of the *G. bicarinatus* species group that are described below in the remarks for those taxa.

Glacidorbis catomus n.sp.

Derivation: *catomus* (Latin)—shoulder, refers to the shouldered whorls.

Type material. HOLOTYPE, AMS C350957. PARATYPES (additional paratypes are listed below): 18 dry and many wet, AMS C202214; 2, QVM 9:1644; 2, TM E23418.

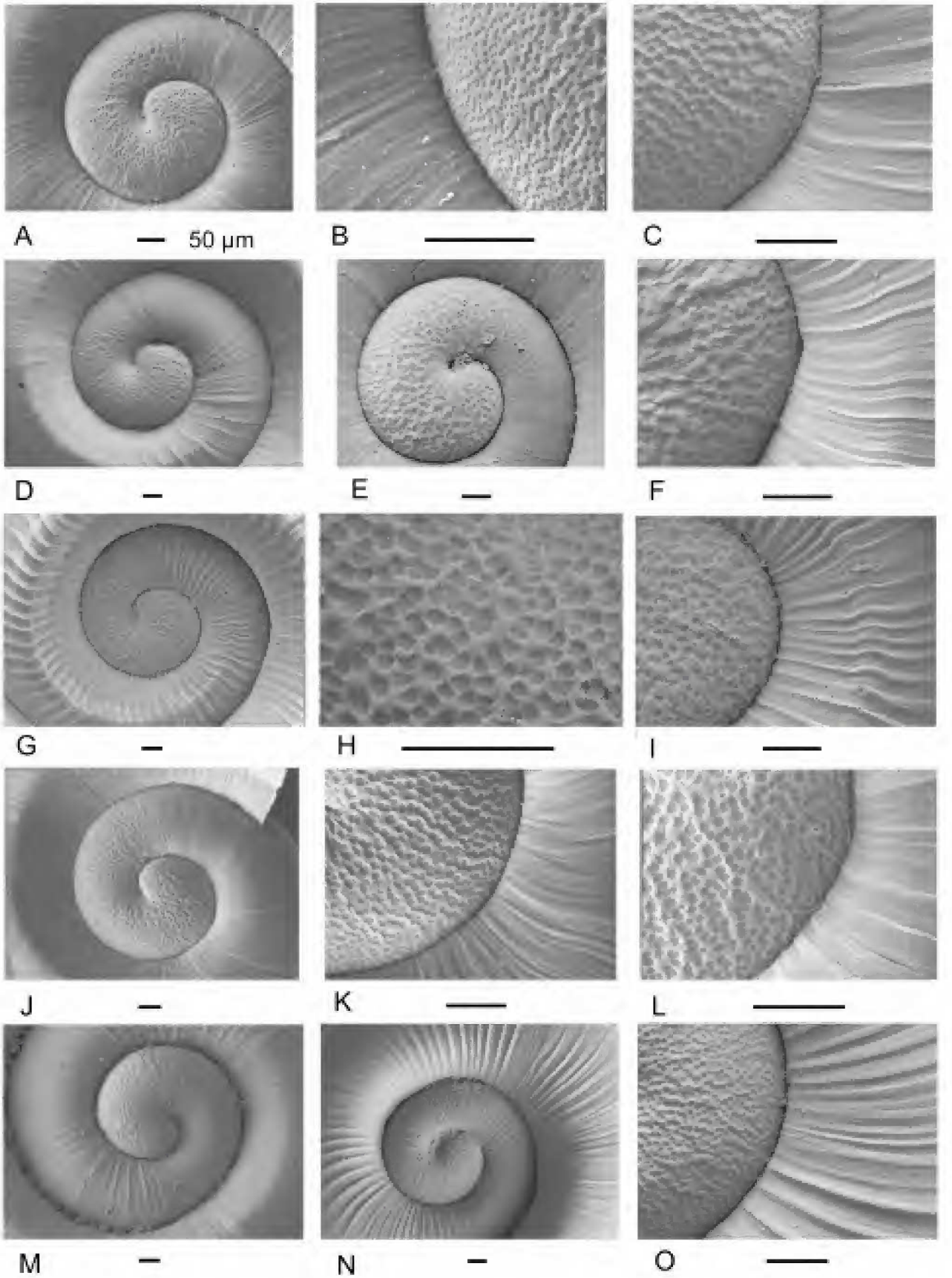
Type locality. Stn TA68, Monazite Ck, tributary of Surveyors Ck on Old Waterhouse Rd, NE Scottsdale, 41°7.77'S 147°34.2'E, 130 m, 27 Jan 1987, WFP JHW & GAC.

Additional paratypes. Stn JW27, Hurst Ck, at Oakdene Rd, 2.5 km W of Scottsdale, 41°9.38'S 147°30.92'E, 100 m, root mats, leaf litter, gravel, 8 Feb 1988, JHW (5, AMS C202329; 6, AMS C363894); stn TA706, same locality, in boggy weed, 5 Feb 1995, SAC & ACM (many, AMS C203970); stn TA67, near tree fern roots in seepage, 27 Jan 1987, WFP JHW & GAC (3, AMS C350050; 1, AMS C351675, many, AMS C353992).

Additional material examined. TASMANIA: stn TA60, Curries River on Beechford Rd 4.9 km N of Lefroy, 41°2.03'S 146°57.77'E, 40 m, 26 Jan 1987, WFP JHW & GAC (1, AMS C202211); stn TA659, tributary of Second River 6 km along Doaks Rd, E of Lilydale, 41°15.38'S 147°16.55'E, 480 m, under rocks in flowing parts, 20 Feb 1989, WFP JHW & FEH (1, AMS C363907); stn JW30, tributary of St Patricks River near TA138, near Weavers Rd Nunamara, 41°23.3'S 147°19.7'E, underground seep near headwaters, 8 Feb 1988, JHW (1, AMS C202330); stn TA69, tributary of Arnon River on Kamona Valley Rd 200 m from Forester Rd turnoff, 41°5.683'S 147°38.383'E, on roots, dead leaves of swordgrass, 27 Jan 1987, WFP JHW & GAC (19, AMS C363890); stn TA72, tributary of Tomahawk River on Oxberry Rd 0.6 km W of junction with Base Rd, 41°1.5'S 147°42.4'E, 160 m, on weed, 27 Jan 1987, WFP JHW & GAC (9, AMS C363903).

Diagnosis. Dorsal carinae weak, often angulation only, at about sutural ¼ to ⅓, ventral carina moderately strong to weak, in inner ⅓ to middle of base; microsculpture of weak growth lines only. Radula with 5–8 cusps and abutting to slightly overlapping articulation.

Description. Shell (Figs. 9A,B,F; 10D,F–K,M) very small (up to 1.5 mm in max. diameter), orthostrophic, near planispiral, up to about 2.7 biangulated whorls. Protoconch (Fig. 9A,B,F) of about 1.0–1.2 whorls, sculptured with minute shallow, irregular pits, borders of pits irregular and wide, forming granulate texture. Protoconch followed by about ⅓ whorl of possible larval shell not clearly demarcated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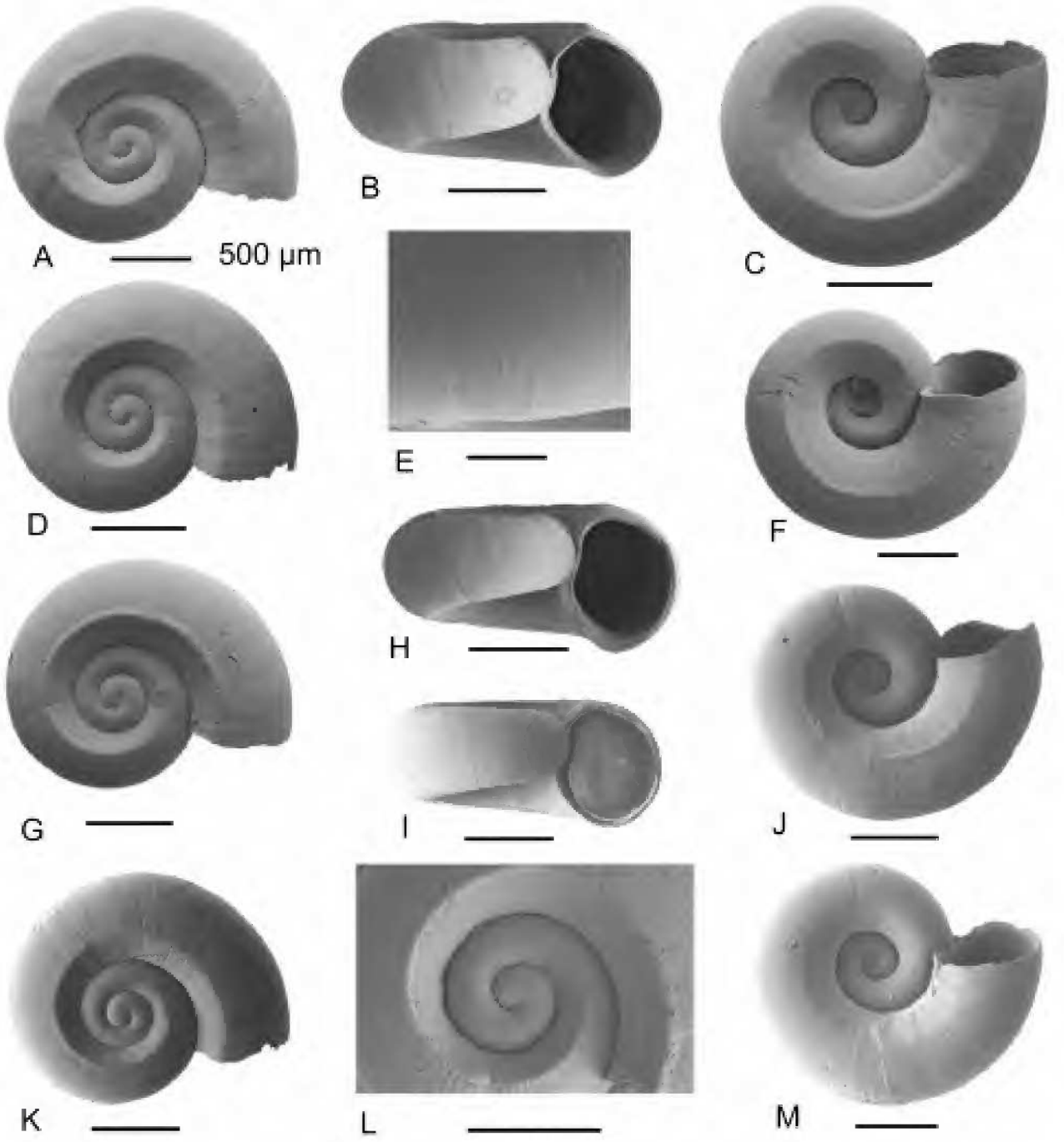

Figure 10. Shells of some Tasmanian members of the *Glacidorbis bicarinatus* species group. A–C,E,L: *Glacidorbis bicarinatus*; holotype (A) (AMS C351694); dorsal view. B,C,E,L: East of Preston, northern Tasmania (paratypes, AMS C202347); lateral and ventral view of two specimens; detail of first part of periphery of last whorl (E); detail of dorsal view (L). D,F–K,M: *Glacidorbis catomus* n.sp. D: holotype (AMS C350957); dorsal view. F–H: Monazite Ck, tributary of Surveyors Ck on Old Waterhouse Rd, NE Scottsdale, Tasmania (paratypes, TA68, AMS C202214). Ventral, dorsal and lateral views of three specimens. I–K,M: Hurst Ck, at Oakdene Rd, W of Scottsdale, Tasmania (paratypes, TA67, AMS C350050); lateral, dorsal and two ventral views of four specimens.

Figure 9 [facing page]. Protoconchs of *Glacidorbis bicarinatus* species group. A,B,F: *Glacidorbis catomus* n.sp. A,B: Hurst Ck, at Oakdene Rd, W of Scottsdale, Tasmania (paratype, AMS C350050); detail of microsculpture (B). F: Monazite Ck, tributary of Surveyors Ck on Old Waterhouse Rd, NE Scottsdale, Tasmania (paratype, AMS C202214); detail of microsculpture. C,D: *Glacidorbis bicarinatus* n.sp.; E of Preston, northern Tasmania (paratype, AMS C202347); detail of microsculpture (C). E: *Glacidorbis otwayensis* n.sp.; holotype (AMS C354937). G–I,L: *Glacidorbis decoratus* n.sp. G,I: tributary of Rapid River, S of Rapid River on Pipeline Rd, NW Tasmania (holotype, AMS C202367); detail of microsculpture (I). H,L: tributary of Mosquito Ck, on Corner Rd, NW Tasmania (AMS C350046); detail of microsculpture (H). J,K: *Glacidorbis rusticus* n.sp.; Squeaky Ck, Wilsons Promontory, Victoria (paratype, AMS C350047); detail of microsculpture (K). M–O: *Glacidorbis atrophus* n.sp. M: Wandle River on Murchison Hwy, N of Waratah, Tasmania (AMS C350045). N,O: tributary of Big Ck, off Tram Rd, S of Wynyard, Tasmania (paratype, AMS C202354); detail of microsculpture (O).

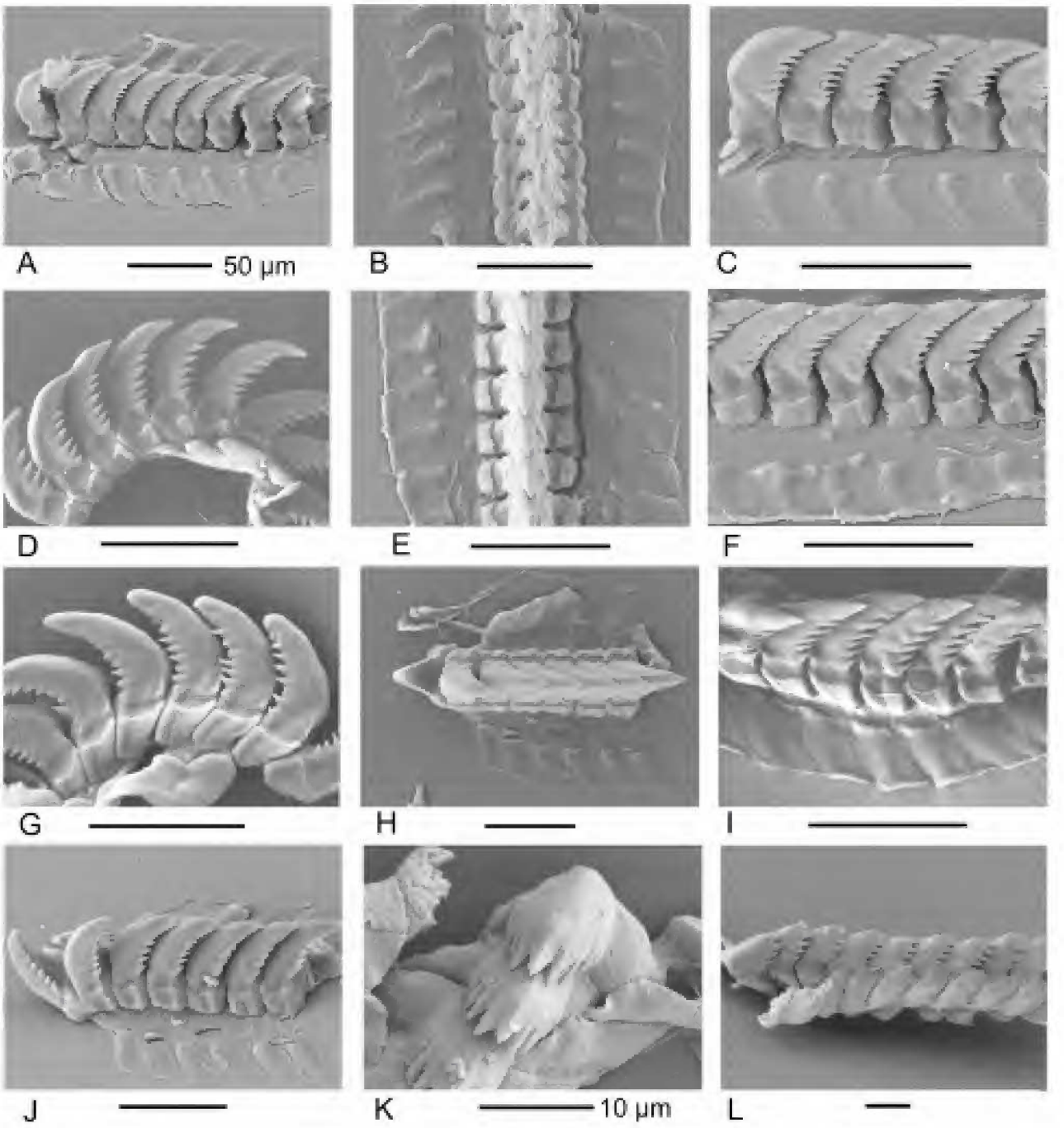

Figure 11. Radulae of *Glacidorbis* and *Benthodorbis*. A,B: *Glacidorbis bicarinatus* n.sp., E of Preston, northern Tasmania (paratype, AMS C202347); lateral and dorsal views. C,D: *Glacidorbis catomus* n.sp. C: Monazite Ck, tributary of Surveyors Ck on Old Waterhouse Rd, NE Scottsdale, Tasmania (paratype, TA68, AMS C202214); lateral view. D: Hurst Ck, at Oakdene Rd, W of Scottsdale, Tasmania (paratype, AMS C350050); lateral view. E,F: *Glacidorbis atrophus* n.sp.; tributary of Big Ck, off Tram Rd, S of Wynyard, NW, Tasmania (paratype, AMS C202354); dorsal and lateral views. G,I: *Glacidorbis rusticus* n.sp.; Squeaky Ck, Wilsons Promontory, Victoria (paratype, AMS C350047); lateral views. H,J: *Glacidorbis decoratus* n.sp.; tributary of Rapid River, S of Rapid River on Pipeline Rd, NW Tasmania (paratypes, AMS C202367); dorsal and lateral views. K,L: *Benthodorbis fultoni* n.sp.; Lake Sorell, Tasmania (paratype, MV F54907); dorsal and lateral views. Scale bars K and L 10 µm, remainder 50 µm.

from teleoconch. Teleoconch microsculpture of fine growth lines, first whorl fine axial growth lines, moderate to weak carina or angulation in dorsal sutural ¼ to ⅓ of whorl; base with moderate to weak carina or angulation in inner ⅓ to middle of whorl, weak to obsolete in some specimens (e.g., AMS C350050). Dorsal surface of whorls on sutural side of angulation strongly sloping into suture; periphery of last whorl evenly convex; ventral surface of last whorl convex (except angulation). Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.59–0.67. Aperture subcircular (9 specimens examined using SEM from type locality, AMS C350050 and AMS C351675). Colour yellow-white to white, opaque to semi-translucent.

Dimensions. See Table 6.

Operculum (Fig. 7A,B) oval (width /length 0.77–0.80), flat, of c. 3.4 (c. 1.4 adult) whorls; width of last whorl/ length of operculum 0.36–0.37. Nucleus large, 0.37–0.41 length of operculum, spiral (about 2 whorls), eccentric. Inner surface with slightly raised spiral ridge surrounding nucleus. Exterior with numerous approximately spirally arranged pustules on last whorl (4 specimens examined from type locality (1) and AMS C350050 (3)).

Radula (Fig. 11C,D) of 18–20 rows (n = 6). Central teeth with 5–8 (usually 6–7) sharp, approximately equal-sized lateral cusps occupying about ⅔ to ¾ length of mesocone. Base wider than long, 0.35–0.47, 1.67–1.83 wider than width of mesocone, outer edges slightly concave to straight, dorsal basal thickening prominent, anterior articulatory thickening stronger than posterior, anterior articulation abuts to slightly overlapped by dorsal part of posterior articulatory area of tooth in front. Width of lateral elements about half their length, not tapering, straight to slightly curved, with posterior edge of inner ends weakly thickened; plates abutting to narrowly separated, anterior edges finely denticulate (9 radulae examined from type material [3] and AMS C350050 [3]).

Distribution (Fig. 8). North-flowing drainages, NE Tasmania.

Remarks. The material attributed to this species shows some variation between and within populations. A few lots (e.g., Fig. 10M) have specimens with a weak to subobsolete keel on the base, but the strength of the keel can vary within single samples (e.g., Fig. 10J,M).

Glacidorbis bicarinatus is larger and has stronger, raised basal and dorsal keels which are more centrally located on the whorls (cf. Fig. 10A with 10D,G,K) and has weak axial costae on the first whorl (Fig. 10L). The base of that species has the spiral cord located centrally and the inner whorl surface (sloping into the umbilical area) is flat, not weakly convex as it is in *G. catomus*.

Glacidorbis catomus is unusual in having the protoconch microsculpture with smaller pits with wider borders which form a granulate surface (Fig. 9B,F). The radula has 18–20 teeth in each row (compared with 21–22 in *G. bicarinatus*) and has 5–8 (usually 6–7) cusps on each tooth rather than 8–9.

Table 6. Shell measurements of *Glacidorbis catomus*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype (AMS C350957)						
1.31	1.59	0.44	0.81	0.72	0.53	2.52
paratypes (AMS C202214)						
1.38	1.57	0.52	0.87	0.73	0.62	2.55
1.51	1.73	0.57	0.87	0.82	0.59	2.65
1.29	1.57	0.44	0.83	0.67	0.60	2.40
additional specimens (AMS C350050)						
1.42	1.72	0.54	0.77	0.75	0.55	2.55
1.53	1.77	0.54	0.75	0.69	0.59	2.65
1.32	1.57	0.45	0.72	0.63	0.50	2.50
additional specimen (AMS C351675)						
1.33	1.62	0.49	0.71	0.69	0.54	2.50

Glacidorbis atrophus n.sp.

Derivation: *atrophus* (Latin, from the Greek *atrophos*)—emaciation, wasting away—refers to the weak spiral keels of this taxon.

Type material. HOLOTYPE, AMS C350958. PARATYPES (9): 2, AMS C202354; 6, AMS C354942; 1, QVM 9:1646.

Type locality. TA536, tributary of Big Ck, off Tram Rd, c. 8 km S of Wynyard, Tasmania, 41°3.28'S 145°41.65'E, 8 Feb 1989, WFP JHW & FEH, pH 6.07, cond. 0.14.

Additional material examined. TASMANIA: stn V1721, Dip River, below falls, 41°2.28'S 145°22.57'E, 28 Jan 1974, Univ. of Tas. (4, MV F60410); stn TA558, Dip Falls, Arthur River area, above falls, 41°2.22'S 145°22.72'E, 210 m, 10 Feb 1989, WFP & JHW (1, AMS C202364); stn C140T, Deep Gully Creek, tributary of Arthur River, at Murchison Hwy, 41°25.467'S 145°33.7'E, rocks and gravel in large stream, 23 Jan 1982, WFP WFPj & JH (3, AMS C363847); stn C139T, Wandle River on Murchison Hwy, N of Waratah, 41°21.81'S 145°34.83'E, 565 m, on weed, on and under stones, roots, 23 Jan 1982, WFP JH & WFPj (1, AMS C350045) (with *Tasmodorbis punctatus*); stn TA536, tributary of Big Ck, 41°3.267'S 145°41.65'E, 80 m, 8 Feb 1989, WFP JHW & FEH (14, AMS C364668); stn TA523, Wollastonite Ck, at Upper Natone Rd, 41°16.62'S 145°48.28'E, 400 m, on rocks and leaves, 6 Feb 1989, WFP JHW & FEH (1, AMS C202352).

Diagnosis. Shell with rather weak dorsal keel at about sutural ¼ and weak to subobsolete ventral keel. Distinct axial costae on spire of teleoconch. Radula with 5–7 cusps and abutting articulation.

Description. Shell (Figs. 9M–O, 12G–J) small (up to 1.8 mm in max. diameter), orthostrophic, near planispiral, up to about 2.7 whorls. Protoconch (Fig. 9M–O) of 1.0–1.2 whorls, sculptured with close, small, deep pits and a few irregular weak axial folds. Teleoconch sculpture of sharp axial riblets with interspaces approximately twice their width, becoming obsolete on last half whorl. Dorsal surface of whorls convex, with weak dorsal ridge forming on penultimate whorl, stronger on last whorl, at about inner ¼ of whorl; periphery of last whorl evenly convex; ventral surface of last whorl convex, with weak axial riblets and having weak to distinct angulation in centre. Base with

Table 7. Shell measurements of *Glacidorbis atrophus*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype						
1.32	1.64	0.49	0.70	0.62	0.56	2.45
paratypes (AMS C202354)						
1.33	1.62	0.45	0.76	0.68	0.54	2.40
1.41	1.69	0.48	0.79	0.71	0.60	2.65
figured specimen (AMS C350045)						
1.47	1.78	0.50	0.67	0.63	0.56	2.70

broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.62–0.65. Aperture subcircular (4 shells examined using SEM from type material [3] and AMS C350045). Colour pale yellow-brown to yellowish-white.

Dimensions. See Table 7.

Operculum (Fig. 7C,F) subcircular (width/length 0.75–0.84), flat, of c. 3 (1 adult) whorls, width of last whorl/length of operculum 0.42–0.46. Nucleus large, 0.38–0.40 length of operculum, spiral (of about 2 whorls), eccentric. Inner surface with slightly raised spiral ridge surrounding nucleus. Exterior with numerous irregular rows of spirally arranged pustules on last whorl (4 examined from type locality).

Radula (Fig. 11E,F) of 18–23 rows. Central teeth with 5–7 sharp, approximately equal-sized lateral cusps occupying about ⅔ length of mesocone. Base 0.18–0.19 wider than long, about 0.44–0.45 wider than width of mesocone, outer edges almost straight to slightly convex, dorsal basal thickening strong, anterior articulatory thickening markedly stronger than posterior, anterior articulation abuts tooth in front. Lateral elements not tapering, moderately curved, width approximately half length, with weakly thickened inner ends; teeth abutting (2 radulae examined from type locality).

Distribution (Fig. 8). North east Tasmania in north flowing drainages from Dip River in the north west to Little Clayton's Rivulet in the mid north coast.

Remarks. This taxon differs from *G. bicarinatus* in having weaker dorsal and ventral ridges placed close to the suture (not in or near the middle of the whorls) and more distinct axial sculpture. *Glacidorbis bicarinatus* in the mid north coast appears to be separated from *G. atrophus* which is further to the west. *Glacidorbis catomus* in the NE of Tasmania has a similar configuration of the keels but lacks the distinct axial costae on the spire.

Glacidorbis decoratus n.sp.

Derivation: *decoratus* (Latin)—ornament. Refers to the ornamented shell of this species.

Type material. HOLOTYPE, AMS C350956. PARATYPES (7): 2, AMS C202367; 4, AMS C355558; 1, QVM 9:1645.

Type locality. Stn TA579, tributary of Rapid River, 3.4 km S of Rapid River on Pipeline Rd, Tasmania, 41°17.5'S 145°18.417'E, on vegetation, 12 Feb 1989, WFP JHW & FEH, pH 6.04.

Additional material examined. TASMANIA: stn TA562, tributary of Fixters Ck at N end of Brittons Swamp, 40°54.783'S 144°57.85'E, 60 m, under and on wood, roots and leaves, 11 Feb 1989, WFP JHW & FEH (2, AMS C363891); stn TA550A, tributary of Mill Ck, tributary of Duck River, 40°59.433'S 145°0.417'E, 40 m, on treefern roots and under wood, 10 Feb 1989, WFP & JHW (1, AMS C363895); stn TA549, Blizzards Ck on Youngs Rd, S of Irishtown, in seeping gully, 40°56.55'S 145°8.983'E, 180 m, wood, leaves and stones, 9 Feb 1989, WFP JHW & FEH (9, AMS C363909); stn TA571, tributary of Mosquito Ck, just before Pipeline Rd on Corner Rd, 40°55.383'S 145°19.483'E, 100 m, on leaves, roots and pieces of wood, 12 Feb 1989, WFP JHW & FEH (6, AMS C350046; many, AMS C353991); stn TA554, Chester Ck, tributary of Arthur River, 41°5.717'S 144°58.917'E, 50 m, under leaves, stones, wood on sides of creek, or on surface if sheltered, 10 Feb 1989, WFP & JHW (3, AMS C363896); stn TA96/16, small tributary on N side of Middleton Creek on Tarkin Rd, 0.5 km from turnoff to Corinna, 41°37.9'S 145°5.52'E, under stones, wood and on roots, 26 Dec 1996, WFP (3, AMS C204079); stn TA585, 16.4 km SW of Rapid River, on Pipeline Rd, 41°23.15'S 145°13.55'E, 380 m, stones, moss and wood, 12 Feb 1989, WFP JHW & FEH (1, AMS C363898); stn TA581, tributary of Little Donaldson River, 11 km SW of Rapid River on Pipeline Rd, 41°20.5'S 145°15.783'E, 460 m, on wood, stones, vegetation and on surfaces, 12 Feb 1989, WFP JHW & FEH (2, AMS C363893); stn C144T, Thirteen Mile Ck tributary of Heazlewood River, junction of Mt Cleveland and Corinna Rds, 41°28.53'S 145°20.45'E, 290 m, weed washings, 24 Jan 1982, WFP JH & WFPj (1, AMS C202189); stn TA592, 28.0 km from Murchison Hwy, on Pieman Rd, 1.9 km W of Wilson River, 41°43.933'S 145°20.783'E, 200 m, on stones in fast flowing areas, 13 Feb 1989, WFP JHW & FEH (1, AMS C363897).

Diagnosis. Shell with strong, typically raised dorsal and ventral keels and distinct, sharp riblets over most of the shell surface. Radula with 4–6 cusps and abutting articulation.

Description. Shell (Figs. 9G–I, 12A–F) small (up to 2.0 mm in max. diameter), orthostrophic, near planispiral, of up to about 2.7 whorls. Protoconch (Fig. 9G–I) of 1.0–1.1 whorls, sculptured with closely spaced pits. Teleoconch sculpture of sharp, distinct axial ribs with interspaces about twice to three times the width of the ribs. Dorsal surface of whorls strongly angled by prominent ridge in inner third of whorl, inner side of whorl steeply inclined to suture. Base with axial sculpture similar to that on dorsal surface; and mid-ventral ridge, typically bearing two spiral ribs; periphery of last whorl evenly convex. Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.65–0.67. Aperture pyriform (7 specimens examined using SEM from type locality and AMS C350046). Colour yellow-brown to yellowish-white.

Dimensions. See Table 8.

Operculum (Fig. 7D,E) oval (width/length 0.72–0.83), flat, of c. 3 (1 adult) whorls, width of last whorl/length of operculum 0.43–0.49. Nucleus large, 0.30–0.39 length of

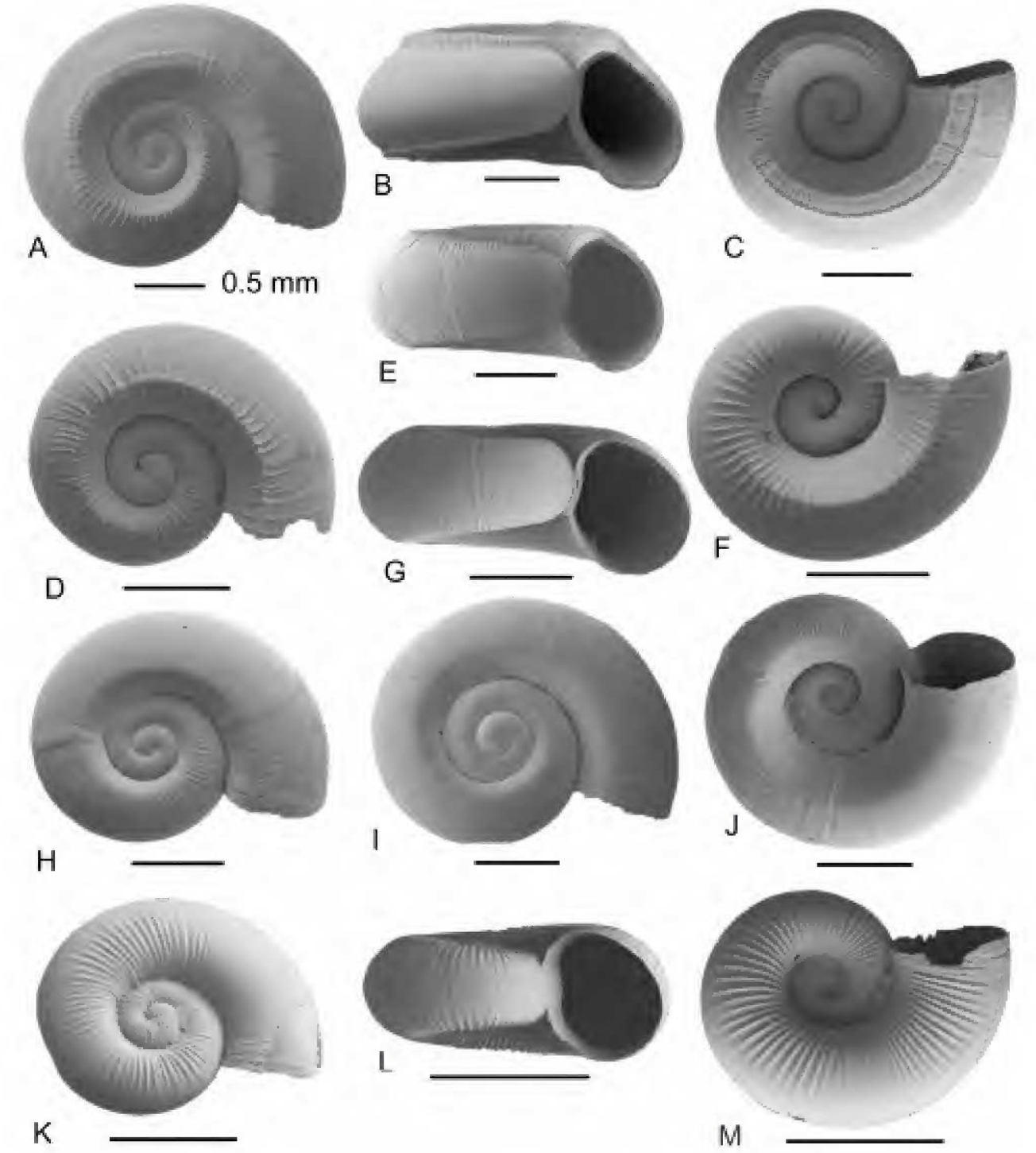

Figure 12. Shells of some Tasmanian members of the *Glacidorbis bicarinatus* species group and *G. costatus* n.sp. A–F: *Glacidorbis decoratus* n.sp. A: holotype (AMS C350956); dorsal view. B–C: tributary of Rapid River, S of Rapid River on Pipeline Rd, NW Tasmania (paratypes, AMS C202367); lateral and ventral views of two specimens. D–F: tributary of Mosquito Ck, on Corner Rd, NW Tasmania (AMS C350046); dorsal, lateral and ventral views of three specimens. G–J: *Glacidorbis atrophus* n.sp. G,J: tributary of Big Ck, off Tram Rd, S of Wynyard, NW Tasmania (paratypes, AMS C202354); lateral and ventral views of two specimens. H: holotype (AMS C350958); dorsal view. I: Wandle River on Murchison Hwy, N of Waratah, Tasmania (AMS C350045); dorsal view. K–M: *Glacidorbis costatus* n.sp. K: holotype (AMS C351684); dorsal view. L,M: Pulbeena Swamp, NW Tasmania (paratypes, AMS C201807); lateral and ventral views.

Table 8. Shell measurements of *Glacidorbis atrophus*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype						
1.63	1.99	0.73	0.98	0.90	0.64	2.60
paratypes (AMS C202367)						
1.57	1.99	0.66	1.02	0.90	0.64	2.55
1.34	1.62	0.54	0.94	0.90	0.58	2.30
figured specimens (AMS C350046)						
1.00	1.21	0.36	0.69	0.67	0.41	2.15
0.82	1.06	0.29	0.64	0.57	0.33	1.95
1.49	1.82	0.59	0.88	0.81	0.57	2.50
additional specimens (AMS C350046)						
1.59	1.96	0.62	0.88	0.81	0.60	2.65
1.36	1.57	0.56	0.82	0.73	0.53	2.50
1.46	1.78	0.58	0.81	0.71	0.56	2.65

operculum, spiral (of about 2 whorls), markedly eccentric. Inner surface with slightly raised spiral ridge surrounding nucleus. Exterior with many rather irregular, approximately spirally arranged pustules on last whorl (5 specimens examined using SEM from type locality [1] and AMS C350046 [4]).

Radula (Fig. 11H,J) of 21–23 rows. Central teeth with 4–6 (usually 5) sharp, approximately equal-sized lateral cusps occupying just over half to ⅔ length of mesocone. Base about twice as wide as long, about 1.54–1.59 wider than mesocone; outer edges slightly concave, dorsal basal thickening strong, narrow, anterior articulatory thickening much stronger than posterior, anterior articulation abuts tooth in front. Width of lateral elements about half length, slightly curved, abutting; weakly thickened towards inner ends.

Distribution (Fig. 8). North west Tasmania mainly in western drainages and northern drainages west of Port Latta.

Remarks. This taxon differs from *G. atrophus* in having much stronger, sharper dorsal and ventral ridges that are typically raised, and stronger axial ribs that extend over the whole dorsal and ventral shell surface. It differs from *G. bicarinatus* and *G. rusticus* in having axial ribs over the whole shell surface, in the dorsal keel usually being more pronounced. Some immature specimens of *G. bicarinatus* superficially resemble this species.

Glacidorbis rusticus n.sp.

Derivation: *rusticus* (Latin)—of the country side.

Type material. HOLOTYPE, AMS C351663. PARATYPES: 3, AMS C350047; many, AMS C353953; 3, MV F82290.

Type locality. EV195, Squeaky Ck at footbridge on track near car park, Wilsons Promontory, Victoria, 39°01.45'S 146°18.67'E, on weeds, 13 Feb 1990, WFP & JHW, pH 5.64, cond. 0.39.

Additional material examined. VICTORIA: Wilsons Promontory: stn EV153, Golden Ck, W of Corner Inlet, 38°44.75'S 146°10.52'E, 20 m, 11 Feb 1990, WFP GAC RdK & DLB (1, AMS C354055); stn EV172, Tin Mine Ck, at Tin Mine Cove, 38°48.66'S 146°25.53'E, 20 m, in water weeds, 14 Feb 1990, WFP & GAC (8, AMS C365981); stn EV27, creek at southern end of Johnny Souey Cave, near road track close to beach, 38°53.67'S 146°28.8'E, 20 m, in weed, 12 Dec 1988, JHW & GAC (1, AMS C365987); stn EV135, swampy area 3.1 km N of Darby Saddle, 38°59.05'S 146°17.15'E, 20 m, in short turf-like sedge, 8 Feb 1990, JHW & ACM (9, AMS C365984); stn EV145, Upper Whisky Ck, minor E tributary, 39°0.1'S 146°18'E, 120 m, leaf litter, 8 Feb 1990, WFP & DLB (5, AMS C354035); stn EV146, Whisky Ck tributary, on E of main creek, second from top, 39°0.167'S 146°17.95'E, 140 m, leaf litter, 8 Feb 1990, WFP & DLB (1, AMS C365976); stn EV36B, Whiskey Ck, seepage, near road, 39°0.383'S 146°17.6'E, 40 m, in leaf litter and weed, 13 Dec 1988, JHW & GAC (many, AMS C365986); stn EV132, Lilly Pilly Ck tributary, 39°0.433'S 146°20'E, 100 m, leaf litter in seepage, 8 Feb 1990, JHW & ACM (4, AMS C354050); stn EV171, Tidal River tributary, E of Lilly Pilly Gully, 39°0.467'S 146°20.617'E, 20 m, weeds, roots, leaves and debris, 13 Feb 1990, WFP & ACM (7, AMS C365978); stn EV188, Squeaky Ck tributary, c. 150 m in (N) from road and c. 15–20 m above swamp, 39°0.55'S 146°18.55'E, 60 m, on leaf litter and debris, 13 Feb 1990, WFP & JHW (1, AMS C353952); stn EV187A, Squeaky Beach Ck c. 60 m from road upstream on N side, 39°0.7'S 146°18.35'E, 20 m, on leaves, 13 Feb 1990, WFP & JHW (many, AMS C353955); stn EV37A, Squeaky Ck (top of) at road, 39°0.7'S 146°18.367'E, 50 m, in leaves etc., in small, seepy, swampy area, 13 Dec 1988, JHW & GAC (many, AMS C354041); stn EV150, same loc., leaf litter and mud, 8 Feb 1990, WFP & DLB (many, AMS C365989); stn EV165, Blackfish Ck, in Sealers Swamp, 39°0.917'S 146°25.15'E, 20 m, ferntree roots out of main flow and in leaves, 10 Feb 1990, WFP & RdK (1, AMS C353960); stn EV138, creek in Sealers Swamp, 39°1.33'S 146°25.55'E, in water weed, 10 Feb 1990, JHW & ACM (2, AMS C353954); stn EV141, Titania Ck tributary, 1 km W of Windy Saddle, on walking track, 39°1.483'S 146°21.95'E, 300 m, leaf litter, 10 Feb 1990, JHW & ACM (4, AMS C354052); stn EV187B, Squeaky Beach Ck, uphill side of road, 39°1.49'S 146°18.67'E, 20 m, small, swampy stream, 13 Feb 1990, WFP & JHW (11, AMS C365982); stn EV170, Titania Ck tributary (no. 3), 1.25 km E of car park, 39°1.5'S 146°21.817'E, 260 m, in leaves in stream, in moss also, 10 Feb 1990, WFP & RdK (3, AMS C353951); stn EV169, Titania Ck tributary, 700 m W of Windy Saddle, 39°1.55'S 146°22.117'E, 320 m, in leaves in stream, 10 Feb 1990, WFP & RdK (5, AMS C353956); stn EV204, Growler Ck (top of), 0.5 km from gate, 39°1.733'S 146°21.15'E, 260 m, leaf litter, 13 Feb 1990, GAC & DLB (2, AMS C354042); stn EV119, Growler Ck tributary, 1 km from gate (E side of Mt Oberon), 39°1.85'S 146°21.183'E, 160 m, in water weeds, 7 Feb 1990, GAC RdK & ACM (1, AMS C365983); stn EV35, Growler Ck tributary, draining Mt Oberon, 39°2.45'S 146°21.217'E, 80 m, in fern roots, leaves, etc., along edges of creek, 13 Dec 1988, JHW & GAC (1, AMS C365985); stn EV155, Little Waterloo Bay camping area, 39°3.367'S 146°25.75'E, 40 m, leaves in small seep at side, 12 Feb 1990, WFP & DLB (1, AMS C353958); stn EV116, Lighthouse Track, 39°3.5'S 146°22'E, 20 m, seepage by road on side of track, in waterweed, 7 Feb 1990, GAC RdK & ACM (many, AMS C354038); stn EV25, Growler Ck, 39°3.75'S 146°22.417'E, 20 m, in weed, 11 Dec 1988, JHW & GAC (1, AMS C354039); stn EV115, Growler Ck, at road bridge, 39°3.77'S 146°22.43'E, 20 m, roots and debris at side, on weeds, 7 Feb 1990, GAC & RdK, ACM (9, AMS C365979); stn EV130, Frasers Ck, near campsite, 39°3.85'S 146°20.383'E, 20 m, on weed and leaves, mostly leaves, 7 Feb 1990, WFP & JHW (7, AMS C354047); stn EV158, Freshwater Ck, second tributary from Waterloo Bay on S side, 39°3.95'S 146°24.75'E, 20 m, on weeds, 12 Feb 1990, WFP & DLB (1, AMS C353959); stn EV183, Freshwater Ck, 3rd tributary from Waterloo Bay, 39°4.51'S 146°24.52'E, 40 m, leaf litter, 12 Feb 1990, WFP & DLB (several, AMS C354045); stn EV184, upper tributary of Growler Ck, 39°4.53'S 146°24.25'E, 60 m, mud and leaf litter, 12 Feb 1990, WFP & DLB (4, AMS C365980); stn EV159, Freshwater Ck, 1.5 km from Waterloo Bay Beach, 39°4.6'S 146°24.7'E, on vegetation, 12 Feb 1990, WFP & DLB (many, AMS C365977); stn EV129, W tributary of Roaring Meg Ck, near camping area, 39°6.35'S 146°23.017'E, 200 m, on moss and leaf litter along edges, 7 Feb 1990, WFP JHW & DLB (6, AMS C353957); stn EV202, Roaring Meg Ck tributary, second creek on Lighthouse track from Roaring Meg campsite, 39°6.517'S 146°23.533'E, 160 m, leaf litter, tree fern mat, 13 Feb 1990, GAC & DLB (1, AMS C354053); stn EV125, First Bridge Ck,

S end of Wilsons Promontory, 39°6.733'S 146°24.183'E, 200 m, leaf litter, overhanging vegetation, mud, etc., 7 Feb 1990, WFP JHW & DLB (many, AMS C354040); stn EV22, same loc., in moss at waters edge, 11 Dec 1988, JHW & GAC (19, AMS C365975).

Material tentatively assigned to this taxon. VICTORIA: Werribee River, picnic spot, 11.5 km NNW of Ballan, 37°29'S 144°10'E, 11 Oct 1983, A.J. Boulton (5 partially decalcified specimens recorded as *G. hedleyi* by Boulton & Smith, 1985 but are similar to the Wilsons Promontory material, MV F52153); Diamond Ck, tributary of Bunyip River, at Mortimore Reserve, Victoria, 37°59.08'S 145°35.52'E, 170 m, in litter and fern roots, 4 Feb 1994, G.R. Macaulay (1, AMS C302557); stn T20 no. 1, Thomson–Aberfeldy junction, Fingerboard spur track, Victoria, 37°48'S 147°19'E, 26 Nov 1976, MV Survey Dept. (1 decalcified specimen identified by B.J. Smith as *G. hedleyi* but has a deeper body—the presence of keels could not be ascertained with certainty, MV F54916).

Diagnosis. Shell surface with weak growth lines and strong keel dorsally and ventrally. Radula with 5–7 cusps and non-overlapping articulation.

Description. Shell (Figs. 9J,K; 13A–F) small (up to 2.1 mm in max. diameter), orthostrophic, near planispiral, of about 2.7 whorls. Protoconch (Fig. 9J,K) of 1.1 whorls, sculptured with numerous, close pits. Protoconch followed by about ⅓ whorl of possible larval shell not clearly demarcated from teleoconch. Teleoconch sculpture of fine growth lines and strong keel in dorsal ⅓ and strong to moderate keel mid ventrally. Dorsal surface of whorls strongly angulated by keel, steeply inclined to suture; some specimens (including holotype) with a groove between keel and suture; periphery of last whorl evenly convex; ventral surface of last whorl angled by keel, otherwise convex. Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.70–0.75. Aperture subcircular (examined using SEM from type locality). Colour pale yellow-brown to yellowish-white; sometimes stained red-brown.

Dimensions. See Table 9.

Operculum (Fig. 7G,H) oval (width/length 0.77–0.84), flat, of c. 3.5 whorls (c. 1.5 adult), width of last whorl/length of operculum 0.37–0.43. Nucleus large, 0.41–0.43 length of operculum, spiral (of about 2 whorls), eccentric. Inner surface with raised spiral ridge surrounding nucleus. Exterior with many irregular rows of approximately spirally arranged pustules on last whorl (examined from 4 specimens from type locality).

Radula (Fig. 11G,I) of about 23 rows. Central teeth with 5–7 (usually 6) sharp, approximately equal-sized lateral cusps occupying about ⅔ to ¾ of length of mesocone. Base about twice as wide as long, about 1.70–1.73 wider than width of mesocone, outer edges nearly straight, dorsal basal thickening well developed, anterior articulatory thickening stronger than posterior, anterior articulation abuts tooth in front but just inside this posterior base of tooth overlaps anterior edge of tooth behind. Width of lateral elements about 1.25 to twice length, straight laterally, abutting, with weakly thickened inner ends, anterior margin finely denticulate.

Several specimens were examined alive from the type locality and the following notes on the living animal made:

The head-foot of the living animal is similar to that of *G. hedleyi*, with long slender tentacles held almost at right angles to the head. The eyes are in the middle of the bases of the tentacles. The foot is narrowly expanded laterally anteriorly, and the anterior margin has a shallow indentation while posteriorly it is bifid. A short "siphon" projects from the posterior corner of the aperture. The head is broad with a short snout. The head and foot are grey laterally and dorsally, the siphon pale grey. The tentacles are unpigmented except for their grey edges. Specimens seen alive from Tin Mine Bay are unpigmented. Three adults were examined for brooded embryos but none were found.

Distribution (Fig. 5). Wilsons Promontory, Victoria and a few localities in eastern Victoria.

Remarks. This species is common and widespread on Wilsons Promontory. Only one intact shell from one locality (Diamond Creek) outside Wilsons Promontory is available, probably in part because of a lack of collecting. An attempt by the senior author to find *Glacidorbis* in Diamond Creek in 1998 failed. Two other records outside Wilsons Promontory are based on decalcified material so are only tentatively assigned to this taxon.

This taxon is similar to *G. bicarinatus* in the disposition and strength of the dorsal and ventral keels, differing only in a few characters. The shell is transparent pale yellowish in the Wilsons Promontory material, while it is white and opaque, or at most only slightly semi-translucent, in *G. bicarinatus*. In addition, spiral microsculpture is absent and the axial costae are not developed on the spire as they are in *G. bicarinatus*. The radula, while generally similar, has a narrower base than that of *G. bicarinatus*, the mesocone extending closer to the outer edges, and the articulation is slightly different. In *G. bicarinatus*, the base adjacent to the posterior articulation is concave and abuts the tooth in front (Fig. 11A). In *G. rusticus*, this part of the base is extended as a weak angulation (Fig. 11G,I) and overlaps the anterior part of the base of the tooth behind it. The radula also differs in having a smaller number of cusps (5–7 compared with 8–9). *Glacidorbis atrophus* differs in having weaker carinae and axial costae whereas *G. decoratus* differs in having even more pronounced carinae and axial costae over the whole surface. *Glacidorbis catomus*, like *G. rusticus*, lacks axial costae but has less pronounced carinae that are closer to the suture and often just angulations.

Table 9. Shell measurements of *Glacidorbis rusticus*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype						
1.47	1.79	0.61	0.94	0.86	0.66	2.70
paratypes (AMS C350047)						
1.46	1.74	0.52	0.89	0.84	0.66	2.55
1.74	2.06	0.70	1.06	0.97	0.71	2.60
1.59	1.86	0.60	0.92	0.87	0.64	2.65
figured specimen (AMS C302557)						
1.38	1.63	0.47	0.81	0.80	0.66	2.60

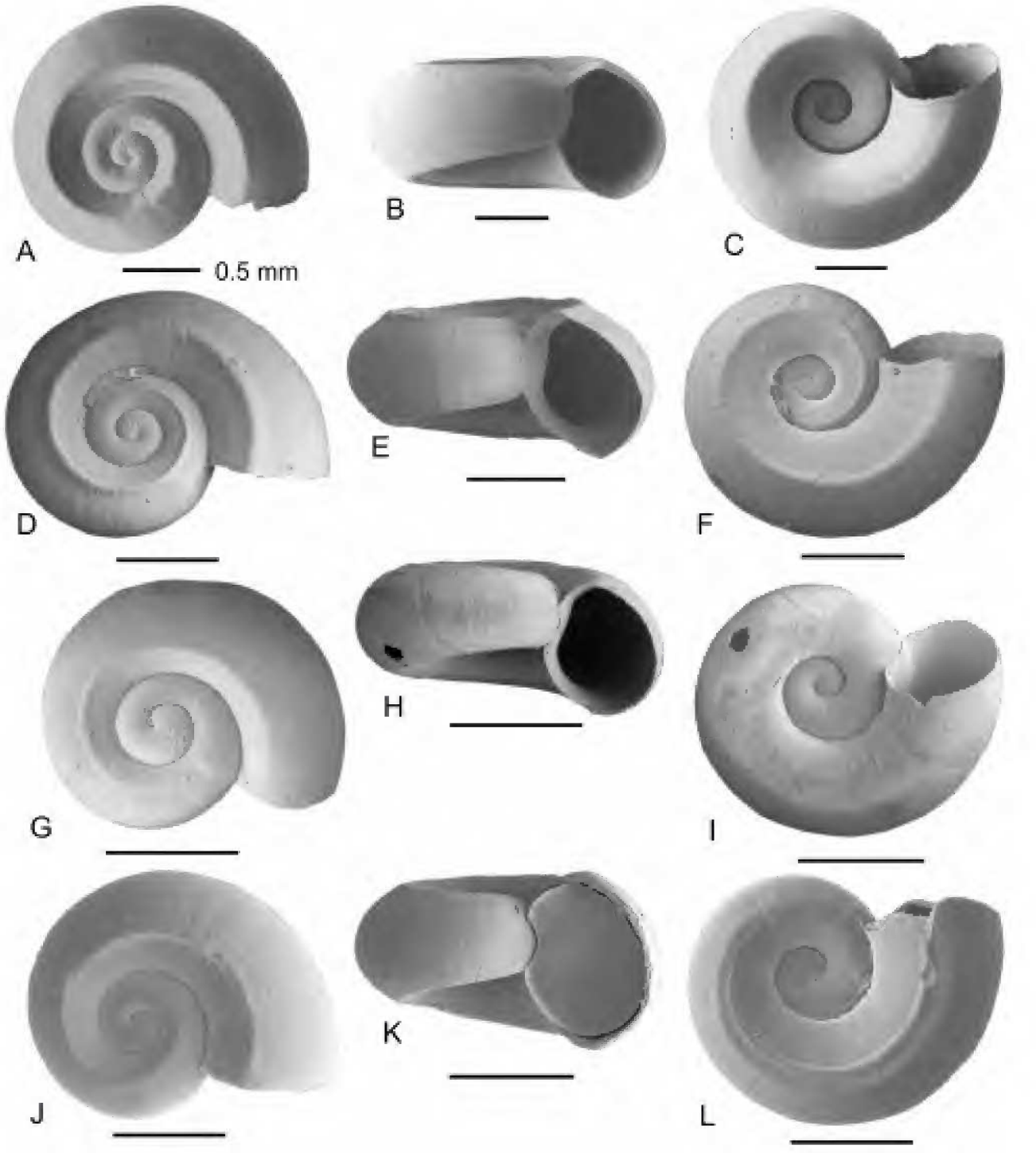

Figure 13. Shells of the Victorian members of the *Glacidorbis bicarinatus* species group and *G. isolatus* n.sp. A–F: *Glacidorbis rusticus* n.sp. Squeaky Ck, Wilsons Promontory, Victoria. A: holotype (AMS C351663), dorsal view. B,C: lateral and ventral views of two paratypes (AMS C350047). D–F: Diamond Ck, tributary of Bunyip River, at Mortimore Reserve, Victoria (AMS C302557); dorsal, lateral and ventral views. G–I: *Glacidorbis otwayensis* n.sp.; holotype (AMS C354937); dorsal, lateral and ventral views. J–L: *Glacidorbis isolatus* n.sp.; Swamp SE of Munro Hut, Kerripit River tributary, Barrington Tops SF, NSW. J: holotype (AMS C351676); dorsal view. K,L: paratypes, lateral and ventral views (AMS C201633).

Glacidorbis otwayensis n.sp.

Derivation. Named after the Otway Ranges where this taxon is found.

Type material. HOLOTYPE, AMS C354937.

Type locality. Stn FA194, small creek at road bridge 3 km S of Nirranda East on road to Curdie Vale, Otway Ranges, Victoria, 38°33.16'S 142°50.45'E, in waterweed, 22 Apr 1988, F.W. Aslin.

Material examined. VICTORIA: Stn V17, 2.3 km from Erskine Rd turnoff (Todds Corner), 38°31.917'S 143°50.817'E, leaves, roots, rocks, mud, 15 Jul 1991, WFP (1, AMS C353940); stn V20, 1.4 km SW from Kennett Rd, 2.3 km NE from Grey River Rd, 38°36.683'S 143°46.983'E, on leaves, moss etc., 15 Jul 1991, WFP (1, AMS C353939).

Diagnosis. Shell minute (about 1 mm in max. diameter), with weak dorsal keel or subangulation, and weak ventral subangulation and relatively large protoconch.

Description. Shell (Figs. 9E, 13G–I) minute (0.9 mm in max. diameter), orthostrophic, near planispiral, of about 2.1 whorls. Protoconch (Fig. 9E) relatively large, of about 1.3 whorls, sculptured with numerous, close pits over all but last quarter whorl. Protoconch followed by about ¼ whorl of possible larval shell not clearly demarcated from teleoconch. Teleoconch sculpture of fine growth lines and weak keel in dorsal ⅓ and subangulation mid ventrally. Dorsal surface of whorls weakly angulated by keel, steeply inclined to suture; periphery of last whorl evenly convex; mid-ventral surface of last whorl subangled, otherwise convex. Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.70. Aperture subcircular (holotype examined using SEM). Colour semi-transparent yellowish-white.

Dimensions. See Table 10.

Operculum paucispiral, with eccentric nucleus. Radula not examined.

Distribution (Fig. 5). Otway Ranges.

Remarks. Only three lots, each with a single specimen that can be assigned to this taxon, which appears to be restricted to the Otway Ranges. This small species is treated as a member of the *G. bicarinatus* species group because of the shell possessing a strongly pitted protoconch and dorsal and ventral angulations. It has a weak angulation in the sutural third of the dorsal surface and a trace of a ventral angulation, but is otherwise smooth. The shell of this species is also similar to that of *G. hedleyi*, especially the forms with a weak dorsal angulation. It differs from that species in its smaller size, weak basal subangulation, and pitted protoconch microsculpture.

The shell of this taxon differs from all of the other members of the *G. bicarinatus* species group in having weaker dorsal and ventral angulations and in its smaller size. The protoconch is relatively larger than in the other species similar to *G. bicarinatus*. In *G. otwayensis*, the width of the protoconch/shell maximum diameter is 0.27 compared with 0.23–0.14 in the other species. It also has fewer whorls, 2.1 compared with about 2.5–2.7 in fully mature specimens of *G. bicarinatus* and similar species.

This taxon is unusual in having (in the one specimen examined using SEM) the last quarter whorl of the initial part of the protoconch smooth, in contrast to strong pitting on most of the protoconch. The coiling is slightly asymmetrical in the holotype but this is not a feature of the other two specimens. The additional specimens also differ in having the weak dorsal keel reduced to an angulation.

Table 10. Shell measurements of the holotype of *Glacidorbis otwayensis*.

	dmin	dmax	mdht	mxht	aph	apw	whl
holotype	0.71	0.89	0.26	0.44	0.4	0.33	2.5

Glacidorbis costatus n.sp.

Derivation: *costatus* (Latin)—ribbed.

Type material. HOLOTYPE, AMS C351684. PARATYPES (additional paratypes listed below): 2, AMS C201807; 10, AMS C353964.

Type locality. Stn TA717, Pulbeena Swamp, S of Smithton, NW Tasmania, 40°52.62'S 145°8.451'E, from banks of old quarry at edge of water, 8 Feb 1995, SAC & ACM.

Additional paratypes. 7 PARATYPES, Pulbeena Swamp, S of Smithton, NW Tasmania, 40°52.62'S 145°8.451'E, 140 cm from surface, in fine peaty marl, coll. N. Porch (QVM 15188); 20 PARATYPES, same loc. and collector, 85 cm from surface, coarse peaty marl (AMS C202369); many PARATYPES, same loc. and collector, 15–20 cm from surface, coarse peaty marl (AMS C202349; 3, TM E23420).

Diagnosis. Shell with well-developed axial costae over whole surface, and weak spiral cords, but lacks spiral keels.

Description. Shell (Figs. 2L, 12K–M) very small (up to 1.1 mm in max. diameter), orthostrophic, near planispiral, of about 2.2 whorls. Protoconch (Fig. 2L) of about 1.1 whorls, sculptured with relatively large pits. Teleoconch sculpture of numerous sharp, strong axial ribs with interspaces about twice their width. About 3 widely spaced weak spiral ribs dorsally, and many fine spiral threads; ventral surface with weak spiral threads; spirals lacking on periphery. Dorsal surface, periphery and base evenly convex. Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter about 0.54. Aperture subcircular (3 specimens examined using SEM from type locality). Colour white.

Dimensions. See Table 11.

Operculum and radula unknown.

Table 11. Shell measurements of the types of *Glacidorbis costatus*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype						
0.90	1.11	0.31	0.49	0.46	0.40	2.20
paratypes (AMS C201807)						
0.82	1.00	0.27	0.43	0.44	0.37	2.10
0.79	0.96	0.29	0.44	0.42	0.36	2.20

Distribution (Fig. 8). Pulbeena Swamp, north west Tasmania (Pleistocene-Holocene).

Remarks. This species is known only as a fossil from Pulbeena Swamp in north western Tasmania. This location is a large (c. 1.7 km^2) swamp at about 30 m altitude. It consists of late Quaternary peats and shelly marls that were exposed in a quarry (now disused). A section exposed during the late 1970's was described stratigraphically and its pollen (Colhoun *et al*., 1982) and ostracod (De Deckker, 1982) sequences analysed.

Glacidorbis costatus occurs through most of the sequence, along with other molluscs, mainly two species of Austropyrgus, which are much more abundant. Because *G. costatus* has not been collected alive, despite rather intensive collecting in the general area, it is assumed to be extinct. The extinction probably occurred when the wet land was drained in the early part of this century (De Deckker, 1982), because *Glacidorbis* is found right through the sequence.

Glacidorbis isolatus n.sp.

Derivation: *isolatus* ("New Latin")—detached, separate.

Type material. HOLOTYPE, AMS C351676. PARATYPES: 2, AMS C201633; 6 dry and many wet, AMS C353962.

Type locality. Stn BT985, swamp SE of Munro Hut, Kerripit River tributary, Barrington Tops SF, NSW, 32°3.7'S 151°34.7'E, near creek, 27 Mar 1985, WFP.

Additional material examined. NEW SOUTH WALES: Stn 1003, NE of Armidale, 23 km E of Guyra, Aberfoyle River, backwaters of stream, 30°12.78'S 151°52.72'E, 23 Nov 1972, G. Witten (3, AMS C364698); stn BT2185, Kholwha Ck, 2 km SE of Mt Polblue on Polblue Trail, near Little Murray picnic area, Barrington Tops, 31°59.04'S 151°27.58'E, 1480 m, small weedy stream, 28 Mar 1985, WFP (9, AMS C306333); stn BT285, 4 km due E of Gloucester Tops Trig Station, 32°3.3'S 151°36.3'E, small stream, 27 Mar 1985, WFP (16, AMS C365963); stn BT004, Barrington Tops, Munroe Hut, 32°3.7'S 151°34.6'E, 21 Dec 1997, WFP (1, AMS C353963).

Diagnosis. Shell bicarinate due to strong dorsal and ventral keels, otherwise smooth except for weak axial growth lines. Protoconch microsculpture of weak pustules.

Description. Shell (Figs. 2F, 13J–L) very small (up to about 1.3 mm in max. diameter), orthostrophic, near planispiral, of about 2 whorls. Protoconch (Fig. 2F) of 1.1 whorls, sculptured with fine pustules. Protoconch followed by about ½ whorl of probable larval shell with fine axial striae and clearly demarcated from teleoconch. Teleoconch sculpture of fine growth lines; dorsally angulated with strong keel in dorsal inner ⅓ which becomes weakly bifid on last whorl. Angulated mid ventrally by strong double keel. Dorsal surface inside keel strongly inclined towards suture; periphery of last whorl evenly convex. Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.65. Aperture oval, angled above and below (types examined using SEM). Colour yellowish-white.

Dimensions. See Table 12.

Operculum. Not examined in detail. Oval, with eccentric nucleus and exterior granules.

Radula. Not examined.

Table 12. Shell measurements of the types of *Glacidorbis isolatus*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype						
1.10	1.34	0.44	0.74	0.60	0.51	1.95
paratypes (AMS C201633)						
0.68	1.23	0.35	0.69	0.70	0.51	1.90
1.02	1.27	0.40	0.68	0.59	0.49	2.05

Distribution (Fig. 5). Barrington Tops and Gloucester Tops, NSW where it is broadly sympatric with *G. hedleyi*, although so far the two species have not been found living together. Also known from one locality in the New England area.

Remarks. This species resembles *G. hedleyi* in having a pustulose protoconch and distinct second larval shell but differs in having a strong bifid carina on both the dorsal and ventral surfaces and in being higher relative to width. This rather poorly known species is found in the Barrington Tops-Gloucester Tops area and two specimens that appear to be this species are known from one location in the New England area considerably further north.

Glacidorbis troglodytes n.sp.

Derivation: *troglodytes* Greek (masculine) inhabitant of holes, caves etc.

Type material. HOLOTYPE, AMS C351666. PARATYPES: 1, AMS C350044; many, AMS C353961; 3, SAM D19069.

Type locality. One Tree Sink Hole (= Wurwurlooloo 5L7), near Mt Gambier, South Australia, 37°49.983'S 140° 46.983'E, in cave, 47 m deep, in fine silt/mud, 9 Feb 1988, M. Apathy (RAN).

Diagnosis. Very small (less than 1.1 mm in diameter), smooth or with a few weak spiral threads, initial part of protoconch sculptured with minute irregular pits.

Description. Shell (Figs. 2I, 6J–M) very small (up to 1.07 mm in max. diameter), orthostrophic, near planispiral, of up to about 2.2 whorls. Protoconch (Fig. 2 I) of about 1.4–1.5 whorls, first half whorl sculptured with very irregular pits, smaller and disappearing on next 0.4 whorls, last half whorl with fine axial threads only. Teleoconch sculpture of fine growth lines; holotype with few weak spiral threads on dorsal surface (Fig. 6J), but these subobsolete in some specimens. Dorsal and ventral surfaces of whorls convex, suture impressed; periphery of last whorl evenly convex. Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.61. Aperture near circular (holotype and paratype examined using SEM). Colour white.

Dimensions. Table 13.

Operculum and radula unknown.

Table 13. Shell measurements of the types of *Glacidorbis troglodytes*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype						
0.88	1.15	0.29	0.46	0.45	0.44	2.10
paratype (AMS C350044)						
1.07	1.31	0.35	0.51	0.50	0.48	2.20

Distribution (Fig. 8). Known only from One Tree Sink Hole, near Mount Gambier, South Australia.

Remarks. This species is similar to *G. hedleyi* but differs in its more fragile, almost planispiral shell, its protoconch microsculpture of minute punctures rather than distinct pustules and in having weak to subobsolete spirals on the dorsal surface. While presently known from a single location, this species may occur in other sink holes in the Mount Gambier area.

Glacidorbis circulus n.sp.

Derivation: *circulus* (Latin), diminutive of *circus*—ring.

Type material. HOLOTYPE, AMS C371939. PARATYPES (29): 11, AMS C363863; 15, AMS C363865; 2, QMV; 1, TM E23419.

Type locality. Stn TA29, Marine Ck, tributary of Mersey R, NE of Railton, Tasmania, 41°19.3'S 146°22.383'E, 180 m, root mats hanging in water, 23 Jan 1987, WFP JHW & GAC, pH 6.50, cond. 0.09.

Additional paratypes. Stn TA30A, Marine Ck on Dallys Rd near Dulverton, NNW Railton, Tasmania, 41°18.78'S 146°23.2'E, 60 m, on gravel, leaves and stones, 23 Jan 1987, WFP JHW & GAC, pH 7.58, cond. 0.09 (AMS C363865).

Diagnosis. Shell with three strong dorsal and ventral spiral cords, innermost angulating whorl dorsally. Protoconch microsculpture of irregular pits.

Description. Shell (Figs. 2H, 14) very small (up to about 1 mm in max. diameter), orthostrophic, near planispiral, of about 2.5 whorls. Protoconch (Fig. 2H) of 1.3–1.4 whorls, sculptured with small, irregular pits. Teleoconch sculpture of fine growth lines and 3 strong, sharp spiral cords, innermost strongest and angulating whorl dorsally at about inner third, ventrally innermost two subequal or innermost stronger, whorl weakly angulated at innermost spiral. Dorsal surface inside main spiral strongly inclined towards suture; periphery of last whorl evenly convex; base convex to subangled. Base with broad umbilicus; ratio of umbilical width to maximum diameter 0.58–0.59. Aperture subcircular (examined using SEM from both type localities). Colour pale yellowish-white to white.

Dimensions. See Table 14.

Operculum oval (width /length 0.77–0.82), flat, of c. 3.5 (c. 1.5 adult) whorls; width of last whorl/length of operculum about 0.43. Nucleus large, spiral, eccentric. Inner

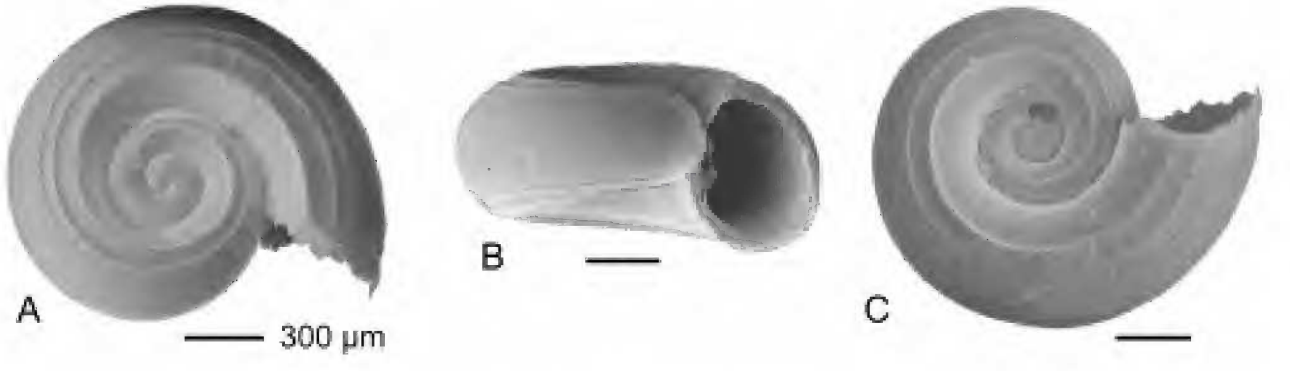

Figure 14. Shells of *Glacidorbis circulus* n.sp. A–C: holotype (AMS C371939); dorsal, lateral and ventral views.

Table 14. Shell measurements of the types of *Glacidorbis circulus*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype						
0.92	1.10	0.33	0.51	0.49	0.36	2.50
paratype (AMS C363865)						
0.78	0.97	0.34	0.50	0.47	0.33	2.30

surface with slightly raised spiral ridge surrounding most of nucleus. Exterior with numerous approximately spirally arranged pustules on last whorl (2 specimens examined from type locality).

Head-foot. Unpigmented.

Distribution (Fig. 8). Mid north coast, known only from Marine Creek, a tributary of the Mersey River.

Remarks. The shells of the two lots of this species are identical, both being collected at different locations in Marine Creek. Most specimens of both lots are slightly decalcified.

This species of *Glacidorbis* is one of two with multiple spirals on both ventral and dorsal surfaces. The other is *G. costatus* which has axial ribs as the predominant sculpture. *Glacidorbis circulus* is superficially similar to two species of *Striadorbis* described below but differs in the protoconch and opercular details that separate *Striadorbis* from *Glacidorbis*.

Glacidorbis? sp.

Type locality. Namba Formation in Union Corporation Bore GB, 70.10–71.63 m, in Lake Pundalpa area, 30°21'S 140°32'E.

Distribution. Middle Miocene deposits, Strezelecki Desert, Central Australia.

Remarks. This species was described in an unpublished report (Buonaiuto, 1982) and referred to by Bunn & Stoddart (1983) but, unfortunately, the 49 specimens on which the description was based cannot be located. From the illustrations and description the smooth shell resembles *G. hedleyi, G. occidentalis, G. tasmanicus* and *G. troglodytes*. The shells of the fossil taxon reach 2.6 mm in diameter and 1.3 mm in height and the protoconch was described as being of one whorl, smooth and undifferentiated from the teleoconch.

Benthodorbis n.gen.

Derivation: *bentho(s)* (Greek)—sea bottom; *dorbis*—derived from *Glacidorbis*.

Type species. *Glacidorbis pawpela* Smith, 1979.

Diagnosis. Shell with slightly hyperstrophically coiled shell; near planispiral, protoconch with axial and spiral threads, slightly heterostrophic. Teleoconch with few, rapidly increasing whorls sculptured with close collabral distinctly prosocline growth lines crossed by fine spiral striae; one species with weak spiral ridge ventrally, otherwise convex. Operculum paucispiral, lacking pustules on exterior, nucleus eccentric, whorls with slightly frilled edges. Radula as for family except mesocone with cusps right to tip and base expanding gradually, not expanded at right angles (Fig. 11K,L; Smith, 1979, figs. 5,6).

Remarks. Differs from *Glacidorbis* in having fine spiral and axial sculpture on the protoconch which lacks distinct punctures or pustules and has a smaller initial part of the first whorl. The teleoconch has fine spiral striae and the axial growth lines are markedly prosocline (orthocline in other glacidorbids). Unlike species of *Glacidorbis*, the base of the shell lacks a distinct umbilical area, being only slightly concave. The radula differs from all other known glacidorbids in having the base expanded gradually, not at right angles to the mesocone, so each tooth is nearly triangular in shape.

The two species of *Benthodorbis* are restricted to two old lakes in Tasmania where they live in the benthos in soft sediment.

Benthodorbis pawpela (Smith, 1979)

Glacidorbis pawpela Smith, 1979: 121, figs. 1,2 (part), 3–6; Smith & Kershaw, 1981: 44 (fig. in text, map 2, p. 119); Bunn & Stoddart, 1983: 55; Smith, 1992: 224.

Type material. HOLOTYPE, TM E10389. PARATYPES (7): 1, TM E10390 (examined wet, with shell intact); 6, MV F30143 (not examined).

Type locality. Elizabeth Bay, Great Lake, Tasmania, 41°54'S 146°46'E, from soft mud bottom at 30 m, W. Fulton, 7 Nov 1975, water temp. < 4°C; same locality, soft mud, 30–40 feet, W. Fulton & BJS, 1 Sep 1978, water temp. 3–4° (wet material from this latter lot examined and is registered MV F54872, 4 decalcified; MV F30147 and three specimens [removed from shells, with one badly damaged shell] and includes the specimen brooding embryos illustrated by Smith [1979, fig. 1]).

Additional material examined. TASMANIA: Elizabeth Bay, Great Lake, 41°54'S 146°46'E, 20 Apr 1977, W. Fulton (1, AMS C350042 ex IFCT); same loc. 30 m, from soft mud, 1 Sep 1978, W. Fulton & BJS (4, MV F54872), from soft mud, 1 Sep 1978, 9–12 m deep, W. Fulton & BJS (4, MV F30147).

Diagnosis. Maximum diameter of shell up to more than 4 mm in maximum diameter (usually more than 2.5 mm), with heterostrophic protoconch and evenly convex ventral surface. Spiral sculpture on teleoconch distinct, with granules at intersections of axial and spiral threads. Radula with 17–18 cusps on either side of mesocone.

Description. Shell (Fig. 15A–D,F) large for family (up to 4.4 mm in max. diameter), slightly hyperstrophic, of up to 3 whorls. Protoconch with initial whorl heterostrophic, of 1.4 whorls, sculptured with subobsolete spiral threads crossing minute, close axial threads, with minute granules at intersections. Teleoconch sculpture of weak prosocline growth lines and, on periphery and base, fine, closely-

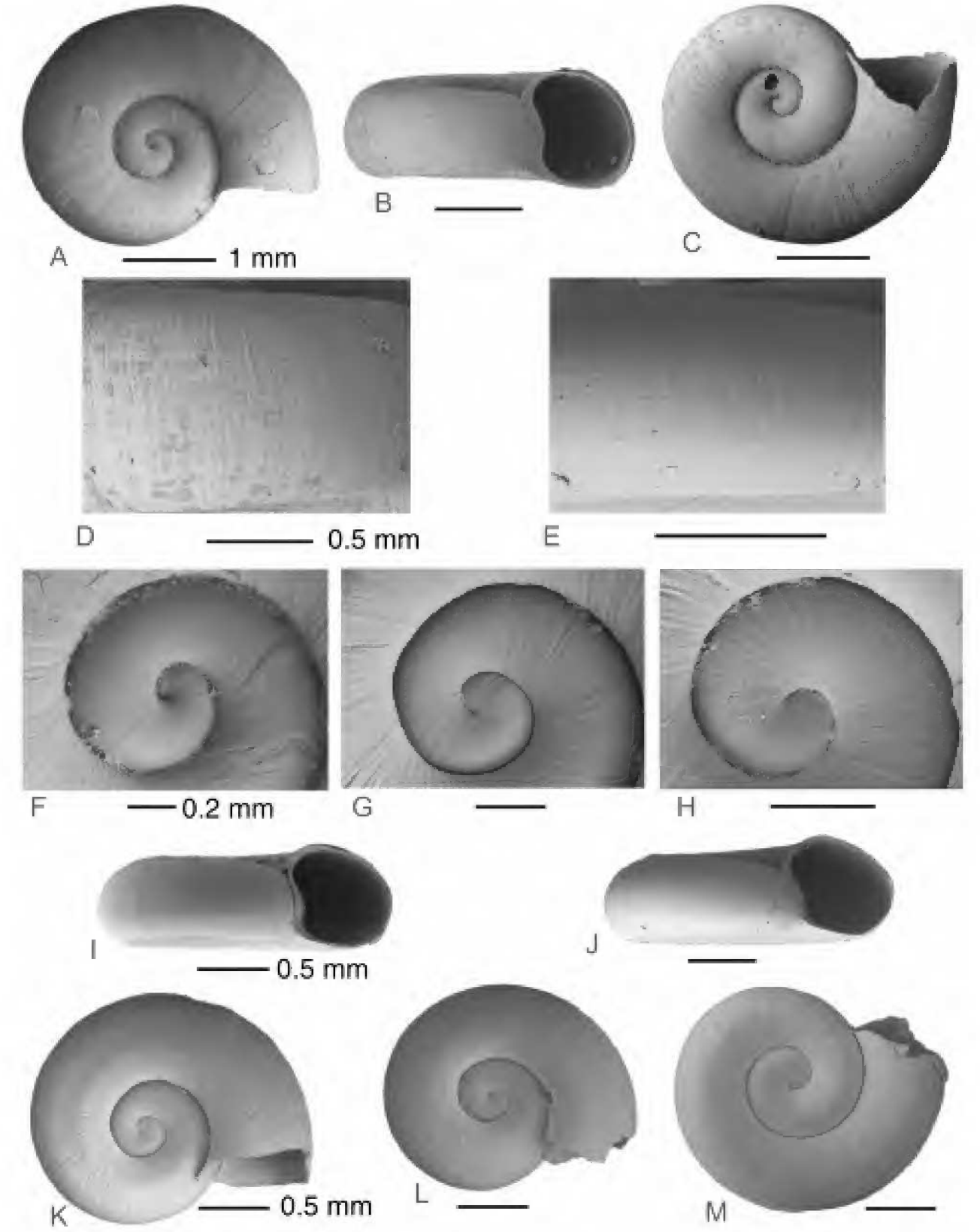

Figure 15. Shells of *Benthodorbis*. A–D,F: *Benthodorbis pawpela*; Elizabeth Bay, Great Lake, Tasmania (1, AMS C350042); A–C: dorsal, lateral and ventral views of one specimen; D: detail of sculpture on periphery of last whorl; F: protoconch. E,G–M: *Benthodorbis fultoni* n.sp.; Lake Sorell, Tasmania; E,G,J,K: holotype (MV F82303); E: detail of sculpture on periphery of last whorl; G: protoconch; J,K: lateral and dorsal views; H,I,L,M: paratype (MV F54907); H: protoconch; I,L,M: lateral, dorsal and ventral views (same specimen). Scale bar lengths indicated at the beginning of each row.

spaced, spiral threads, granulose at many intersections. Dorsal and ventral surfaces of whorls, and periphery convex, suture impressed; dorsally edge of whorl margining suture steep on last half of last whorl, slightly curved back towards outer edge of shell. Base with broad, shallow umbilical area. Aperture weakly pyriform (examined using SEM from AMS C350042). Colour brown, imparted by the rather thick periostracum.

Dimensions. See Tables 15 and 16.

Smith (1979: 122) notes that the shell of a dissected female has a maximum diameter of 4.4 mm and has 3 whorls, markedly larger than any of the measured types.

Operculum (Smith, 1979, fig. 4) paucispiral, oval, flat, of about 2.5 whorls (about 1.5 adult), last whorl wide, width of last whorl/length of operculum 0.34. Nucleus about 0.15 length of operculum, of about 1 whorl, eccentric. Inner surface and exterior microsculpture not described (details from Smith, 1979: 121 and fig. 4).

Radula (Smith, 1979: 121, figs. 5,6) of 22–26 rows. Central teeth with 17–18 sharp, approximately equal-sized lateral cusps occupying almost all length of mesocone. Base slightly wider than width of mesocone, dorsal basal thickening weak, anterior and posterior articulatory thickenings weakly developed, anterior articulation abuts tooth in front, anterior articulation stronger than posterior. Details of lateral elements unknown (details from figures and description of Smith, 1979).

Mantle cavity contains 5 embryos in the large female dissected by Smith (1979), the most anterior by far the largest, the shell being 1.3 mm in maximum diameter and of three quarters of a whorl.

Distribution (Fig. 17). Known only from Great Lake, Tasmania, at a depth of up to 30 m.

Remarks. Smith (1979) separated this species from the three other described species at the time (including *"G". magallanicus* Meier-Brook & Smith, 1976 from Chile) on the basis of its larger shell and the more numerous denticles on the central teeth of the radula. In addition, several important apomorphic characters of this species differentiate it from other members of the family. The granulose teleoconch sculpture is unique, as is the small initial whorl of the slightly heterostrophic protoconch. Moreover, the protoconch, like that of the next species, is weakly spirally sculptured and has distinct axial threads.

Table 15. Shell measurements of the types of *Benthodorbis pawpela* (from Smith, 1979).

dmin	dmax	whl
holotype		
3.0	3.6	2.75
paratypes		
2.2	2.7	2.0
1.6	2.2	1.5
2.5	3.0	2.5
3.1	3.7	2.75
2.5	3.0	2.25
1.9	2.5	1.75
1.9	2.4	1.5
2.0	2.5	1.75
2.9	3.5	2.5

Table 16. Shell measurements of a specimen of *Benthodorbis pawpela*.

dmin	dmax	mdht	mxht	aph	apw	whl
figured specimen (AMS C350042)						
2.82	3.43	1.03	1.44	1.37	1.25	2.25

Benthodorbis fultoni n.sp.

Derivation. Named for Dr Wayne Fulton, Director of the Inland Fisheries Commission of Tasmania, who collected the material.

Type material. HOLOTYPE, MV F82303 (ex 54905). PARATYPES (7): 1 dry, AMS C350043; 2 wet, MV F54905; 4 wet, MV F54907.

Type locality. Stn 5, Lake Sorell, Tasmania, 42°4.49'S 147°11.63'E, 02 Feb 1981, W. Fulton.

Additional material examined. TASMANIA: stn 3, Lake Sorell, 42°4.94'S 147°13.23'E, 27 Jan 1981, W. Fulton (2 wet, MV F54906).

Diagnosis. Maximum diameter of shell only slightly more than 2 mm, with near homostrophe protoconch and weak angulation or weak ridge on ventral side about ¾ of width of whorl from suture. Spiral sculpture on teleoconch weak and simple. Radula with 4 cusps on either side of mesocone.

Description. Shell (Fig. 15E,G–M) small (up to 2.1 mm in max. diameter), slightly hyperstrophic, of up to 2.3 whorls. Protoconch nearly homostrophic, of 1.2 whorls, sculptured with fine, closely spaced spiral threads crossing minute, close axial threads, with weak granules at intersections. Teleoconch sculpture of weak prosocline growth lines and a few weak spiral threads, especially on outer part of base. Dorsal surface of whorls convex, edge of whorl at suture very steeply inclined; suture impressed; periphery of last whorl evenly convex; ventral surface of last whorl with weak angulation or weak ridge at about ¾ of width of whorl from suture. Base with broad, shallow umbilical depression. Aperture sub-pyriform, slightly oblique (holotype and paratype examined using SEM). Colour white, periostracum brown.

Dimensions. See Table 17.

Operculum (Fig. 16F) paucispiral, oval, flat, of about 2.4 whorls (1.4 adult), last whorl wide, width of last whorl/length of operculum 0.37. Nucleus about 0.23 length of operculum, of about 1 whorl, eccentric. Inner surface not observed; exterior sculpture of growth lines only (one specimen examined by SEM from MV F54907).

Radula (Fig. 11K,L) with central teeth having about 4

Table 17. Shell measurements of types of *Benthodorbis fultoni*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype						
1.74	2.13	0.57	0.81	0.80	0.72	2.25
paratype (AMS C350043)						
1.58	1.91	0.54	0.76	0.72	0.64	2.10

sharp, approximately equal-sized lateral cusps occupying almost all length of mesocone. Base wider than width of mesocone, dorsal basal thickening weak, anterior and posterior articulatory thickenings weakly developed, anterior articulation slightly underlies tooth in front. Lateral elements parallel-sided, about 2.3 times longer than wide, narrowly spaced, details of inner surface not known (one specimen examined by SEM from MV F54907).

Distribution (Fig. 17). Lake Sorell, Tasmania.

Remarks. Smith (1985: 123) referred to this species as a "further, unknown species recorded from Lake Sorell (Fulton, 1983)". It differs from *B. pawpela* in its smaller shell, which has a near homostrophe protoconch with slightly larger initial whorl (although smaller than in species of *Glacidorbis* and *Tasmodorbis*), but has similar protoconch microsculpture. The ventral side has a weak angulation or weak ridge about ¾ of width of whorl from the suture whereas the whorls of *B. pawpela* are evenly convex. The teleoconch with similar microsculpture in the two species but the spirals are less distinct in *B. fultoni* and no granules are formed at the intersections of the spiral and axial threads.

While the radular details of both species are not particularly well known, *B. pawpela* differs markedly from *B. fultoni* in having many more cusps on the teeth (17–18 on each side compared with 4).

Striadorbis n.gen.

Derivation: *stria* (Latin)—furrow, channel, line; *dorbis*—derived from *Glacidorbis*.

Type species. *Valvata*(?) *pedderi* Smith, 1973.

Diagnosis. Shell differing from *Glacidorbis* in being planispiral, and in having spiral microsculpture on latter part of protoconch and (at least) early teleoconch. Protoconch with pustules in initial part, teleoconch whorls keeled or evenly rounded. Operculum circular with overlapping whorls and central nucleus. Radula with equal-sized cusps on mesocone but differs from *Glacidorbis* in having major articulation at posterior side of tooth base.

Remarks. Ponder (1986) provides some anatomical details of the type species, which differ from *G. hedleyi* in the following details: (*a*) the pallial cavity is longer and narrower and the rectum longer; (*b*) the mantle lobe is shorter; (*c*) the vagina is large and contains a prominent internal fold; and (*d*) the penis is narrower and the praeputium contains fewer glandular protuberances that are rounded distally, not disk-like as in *G. hedleyi*.

Like *G. hedleyi, Striadorbis pedderi* appears to be a protandrous hermaphrodite but, unlike *G. hedleyi*, no evidence suggests that brooding occurs in *S. pedderi* (see below).

The major articulation on the central teeth is reversed in *Striadorbis* compared with *Glacidorbis*, there being a large boss in front in *Glacidorbis* while the major thickening is posterior in *Striadorbis*. The condition in *Glacidorbis* is similar to that in *Gondwanorbis magallanicus* (Meier-Brook & Smith, 1976, fig. 7). The pustulose protoconch microsculpture is also seen in a few species of *Glacidorbis*.

Striadorbis pedderi (Smith, 1973)

Valvata(?) *pedderi* Smith, 1973: 430.

Glacidorbis pedderi.–Meier-Brook & Smith, 1976: 191; Smith, 1979: 123, fig. 2 (part); Smith & Kershaw, 1979: 41 (fig. in text); Smith & Kershaw, 1981: 43 (fig. in text, map 1 [p. 119]); Ponder, 1986: 75–76, fig. 21; Bunn & Stoddart, 1983: 55; Smith, 1992: 224.

Type material. HOLOTYPE, TM E8543. PARATYPES (6): 3, TM E6443, TM E8544; 1, MV F27938; 2, MV F27939 (on SEM stub), MV F27937 (serial sectioned individual) (details from Smith, 1973).

Type locality. In small hole in plain just south of Lake Edgar (now drowned as part of Lake Pedder), J.L. Hickman, 17 May 1972. Paratypes from Lake Pedder, Lake Maria, and Lake Edgar, in shallow water on weed and rushes with a net, J.A. Dartnall, 12 Feb 1967.

Additional material examined. TASMANIA: Lake Dora, 41°57'S 145°39'E, rock fauna, 18 Feb 1988, IFCT (7, AMS C354007); stn JW4, Orion Lake, Central, 41°36'S 146°12'E, short grassy weed beds near edge, 2 Feb 1988, JHW (7, AMS C363870); stn JW19, Lake Butters, E of Walls of Jerusalem, 41°48.9'S 146°22.6'E, 1250 m, rocky, cobbly shoreline, 5 Feb 1988, JHW (11, AMS C202326) (with *T. punctatus*); stn JW15, New Years Lake, N of Great Pine Tier, 41°50.4'S 146°22.8'E, at back of pond in water weed, 4 Feb 1988, JHW (1, AMS C363878); stn TA130, tributary of Split Rock Ck, 2.8 km NE of Liawenee on Lake Hwy, 41°52.8'S 146°41.283'E, 1040 m, in sedges, 7 Feb 1987, WFP & GAC (1, AMS C350048); stn JW13, Lake Rotuli, W of Great Pine Tier, 41°54.6'S 146°20.5'E, in sedges, 3 Feb 1988, JHW (2, AMS C202324); stn JW5, Junction Lake, SW of Lake Meston, 41°55.3'S 146°11'E, in sedge and algae, FBA sweeps, 2 Feb 1988, JHW (14, AMS C202319); stn JW24, Lake Olive—deep sided lake, near Great Pine Tier, 41°55.7'S 146°20.4'E, short turfy weed in shallows, 5 Feb 1988, 0–0.3 m deep, JHW (many, AMS C202327); Lake Naomi, 41°56'S 146°22'E, rock fauna, 27 Nov 1986, IFCT (1, AMS C354017); stn JW11, small lake south of Eagle Lake, 41°56.5'S 146°15.4'E, steep-sided muddy banks, seeps also muddy, 3 Feb 1988, JHW (10, AMS C202323); Orion Lakes, 41°57'S 146°8'E, rock fauna, 1 Feb 1988, IFCT (11, AMS C354025); stn JW10, Lake Malbena, 41°57'S 146°16.2'E, sedge swamp in one bay, lilies in another, 3 Feb 1988, JHW (many, AMS C202322); stn JW6, Ling Roth Lake, 41°57.2'S 146°13.2'E, 1020 m, bouldery shoreline, muddy silty substrate, 2 Feb 1988, JHW (6, AMS C363910); stn JW3, Lake Riengeena, SW of Mountains of Jupiter, 41°58.3'S 146°10.02'E, 1160 m, in gravel and weed along beach, 1 Feb 1988, JHW (4, AMS C363873); Lake Riengeena, 41°59'S 146°10'E, rock fauna, 1 Feb 1988, IFCT (several, AMS C354027); TA 615, Gordon River just below (downstream) Camerons Flat, 42°30.62'S

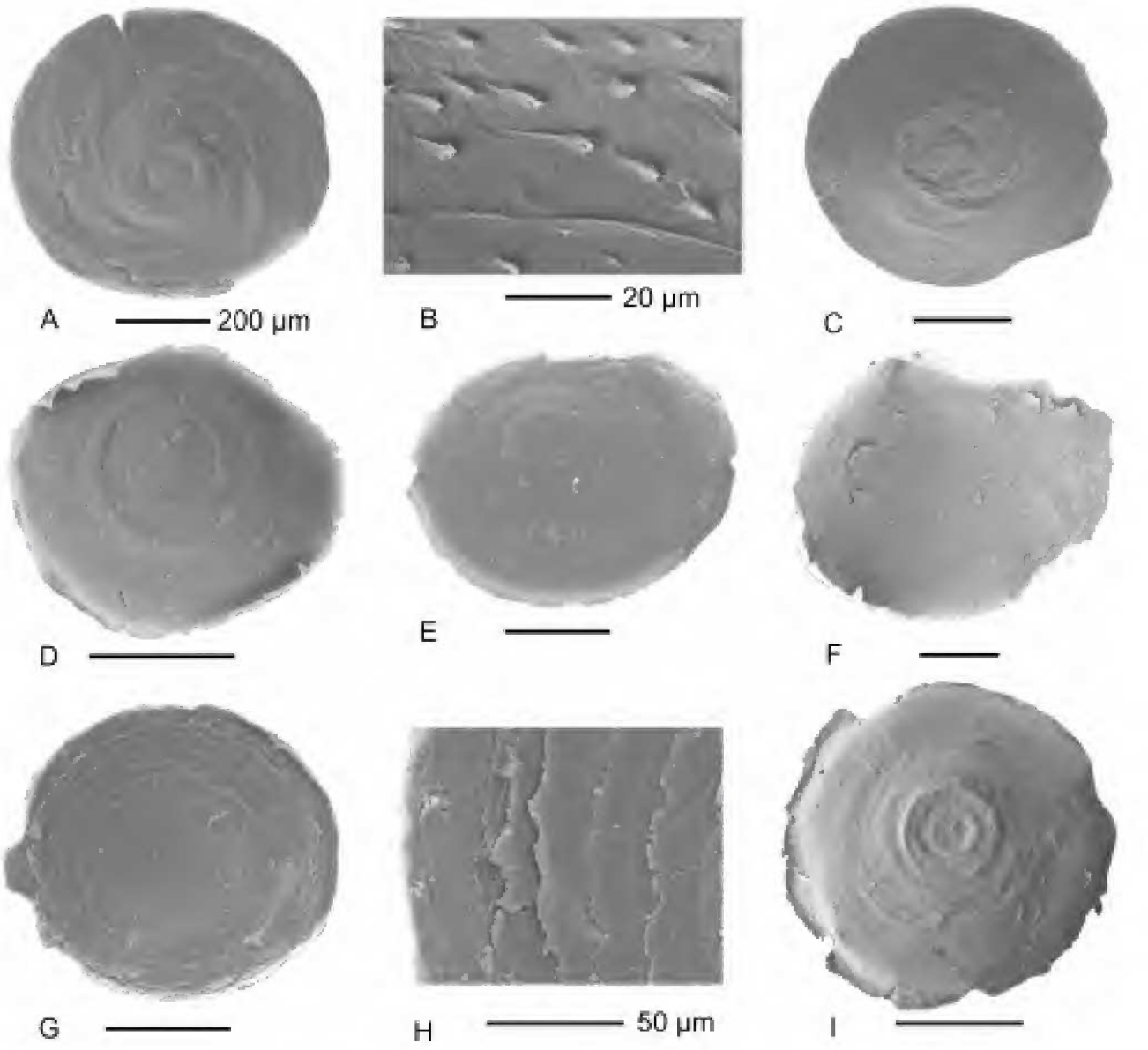

Figure 16. Opercula of *Striadorbis, Tasmodorbis* and *Benthodorbis*. A–C: *Striadorbis pedderi*. A,B: Gordon River just below Camerons Flat, SW Tasmania (AMS C350020); outer side and (B) detail of outer surface ornament. C: NE of Harlequin Hill 850 m off Scotts Peak Rd, SW Tasmania (AMS C202191); inner surface. D: *Striadorbis spiralis* n.sp.; Fitzroy River on Princes Hwy between Portland and Port Fairy, Victoria (paratypes, AMS C351209); outer side. E: *Striadorbis janetae* n.sp.; Last R., tributary of Ansons R. on Ansons Bay Rd, NE Tasmania (AMS C363861); outer side. F: *Benthodorbis fultoni* n.sp.; Lake Sorell, Tasmania (paratype, MV F54907); outer side. G–I: *Tasmodorbis punctatus* n.sp.; tributary Lockwood Ck, near end of Lockwood Creek Rd, NW Tasmania (AMS C364664); outer (G), inner (I) and detail of outer surface (H). Scale bars for figures A,C–G,I 200 µm.

145°40.5'E, small lake on E side, 14 Feb 1989, WFP & FEH (1, AMS C351674; many, AMS C353989; 2, AMS C350020); Lake Nive, 42°0'S 146°18'E, rock fauna, 2 Feb 1988, IFCT (3, AMS C354002); stn JW2A, unnamed lake between Travellers Rest Lake and Mountains of Jupiter, 42°0.3'S 146°13.5'E, 1120 m, 1 Feb 1988, JHW (10, AMS C363869); Lake Ina, 42°2'S 146°17'E, rock fauna, 1 Feb 1988, IFCT (2, AMS C353999); stn JW1, unnamed lake between Lakes Ina and Travellers Rest, 42°2.5'S 146°15.7'E, around boulders and in sedge, 1 Feb 1988, JHW (2, AMS C202316); stn JW37, Sandfly Ck at Scotts Peak Rd, 42°54.48'S 146°22.3'E, in tree roots and leaf litter, 11 Feb 1988, JHW (1, AMS C363866); Sanctuary Lake, 42°56'S 146°2'E, rock fauna, 18 Feb 1989, IFCT (many, AMS C354026); stn C179T, NE of Harlequin Hill 850 m off Scotts Peak Rd, 42°58.32'S 146°20.95'E, 260 m, in swamp, on submerged moss in sluggish main pond, 27 Jan 1982, WFP JH & WFPj (3, AMS C202191; many, AMS C355561); stn SWT2, Davey River, above gorge, 43°9'S 145°56'E, 40 m, under large boulders, on sand/gravel base, 10 Feb 1987, JHW (1, AMS C202310); stn TA42, Brushy Rivulet on Bryans Rd WSW of Birralee, Tasmania, 41°25.983'S 146°44.2'E, in weed, 25 Jan 1987, WFP JHW & GAC (1, AMS C354939) (one poor specimen tentatively assigned to this species).

Decalcified material identified as "G." pedderi by B.J. Smith. Stn GR221, Gordon River, just upstream from Butler Island, "perched" lake, 42°33.78'S 145°40.43'E, on aquatic plants, 25 Jan 1976, Uni. of Tas.

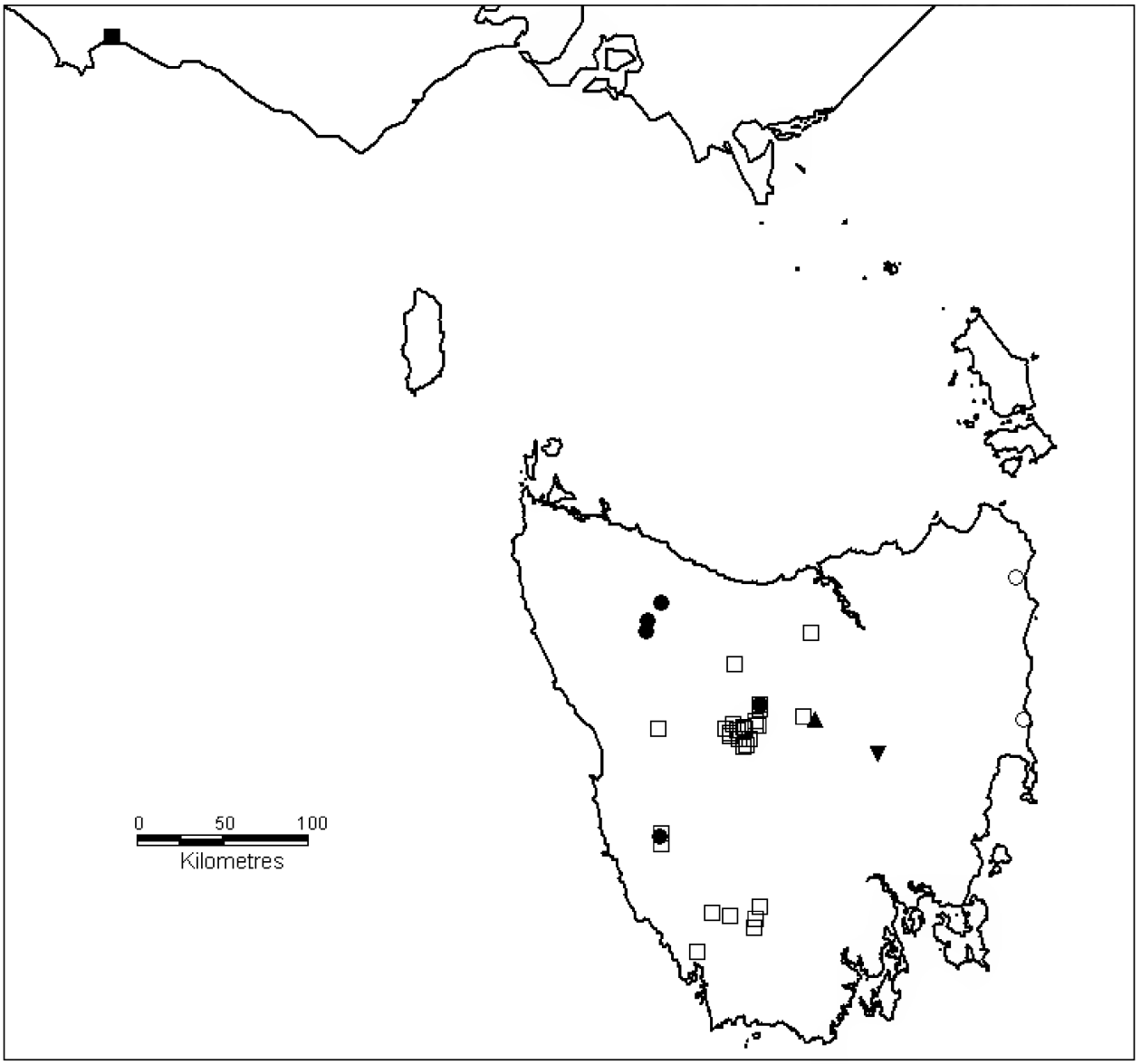

Figure 17. Distribution of species *Benthodorbis pawpela* (▲), *B. fultoni* (▼), *Striadorbis pedderi* (□), *S. spiralis* (■), *S. janetae* (○) and *Tasmodorbis punctatus* (●).

(several, MV F54904; 5, MV F54909); Lake Pedder, 42°57'S 146°10'E, 10 Mar 1972, A. Neboiss (1, MV F54903); Lake Edgar, 43°1'S 146°20'E, open water, 17 May 1972, Uni. of Tas. (2, MV F54873; 3, MV F54874).

Diagnosis. Shell with keel on mid-dorsal and mid ventral surface of whorls, fine spiral threads present over whole surface or mainly on juvenile shell; periphery usually with spiral threads.

Description. Shell (Figs. 18A–C,F; 19) small (up to 2 mm in max. diameter), planispiral, of up to 3.25 bicarinate whorls. Protoconch (Fig. 18A–C,F) of about 1.2 convex whorls (distinction between protoconch and teleoconch not clear), initial part sculptured with small pustules, latter part with several (approx. 8–10) rather uniform spiral threads that continue on to teleoconch. Teleoconch sculpture of axial growth lines crossed by few spiral threads which become subobsolete to obsolete on last whorl in typical specimens, in others remaining across last whorl; prominent sharp spiral keel in middle of dorsal and ventral parts of whorl, weak ventrally in some specimens. Periphery of last whorl evenly convex, usually with spiral threads. Base with broad, shallow umbilicus bordered by keel or ridge, ratio of umbilical width to maximum diameter 0.8. Aperture subcircular except for dorsal and ventral angulations caused by spiral keels (examined using SEM from AMS C202191, AMS C350020 and AMS C350048). Colour yellow-brown to yellow, with last part of last whorl white to transparent.

Dimensions. See Tables 18 and 19.

Operculum (Fig. 16A–C) circular, concave, of c. 4.5 (about 2.5 adult) overlapping whorls but difficult to estimate, width of last whorl/length of operculum 0.18. Nucleus large, about 0.19–0.25 width of operculum, appears

to be spiral, perhaps with about 2 whorls, central. Inner surface with weak rim around nucleus. Exterior with about 10–13 rather irregular rows of spirally arranged pustules on last whorl (examined using SEM, 3 specimens from AMS C202191 and 2 from AMS C350020).

Table 18. Shell measurements of types of *Striadorbis pedderi* (from Smith, 1973).

dmin	dmax	mxht	whl
holotype			
1.61	1.96	0.88	3.0
paratypes			
1.00	1.23	0.42	
1.00	1.23	0.58	
0.85	1.11	0.58	
1.04	1.35		3.0
1.31	1.65		3.0

Radula (Fig. 20A,D,F) of 15–21 rows. Central teeth with 7–8 sharp, approximately equal-sized lateral cusps (some bifid on some teeth in specimen from AMS C202191) occupying about ⅔ length of mesocone. Base 3 times wider than long, about twice width of mesocone; outer edges straight to slightly convex, dorsal basal thickening well developed and clearly delineated, anterior articulatory thickening weaker than posterior articulatory thickening, anterior articulation overlapped by tooth in front. Width of lateral elements about ⅔ length, slightly tapering distally, with rounded, slightly thickened inner ends, spaced at about ¼ of maximum width (examined using SEM, 3 from AMS C202191 and 2 from AMS C350020).

Table 19. Shell measurements of *Striadorbis pedderi*.

dmin	dmax	mdht	mxht	aph	apw	whl
figured specimens (AMS C202191)						
1.53	1.78	0.45	0.68	0.62	0.55	2.65
1.25	1.48	0.38	0.64	0.59	0.51	2.30
1.42	1.70	0.45	0.61	0.57	0.59	2.55
figured specimens AMS C350020						
1.64	1.96	0.50	0.69	0.68	0.66	2.65
1.50	1.77	0.46	0.66	0.63	0.55	2.70
additional specimen (AMS C350048)						
1.59	1.94	0.44	0.74	0.65	0.62	2.55
additional specimen (AMS C351674)						
1.74	2.02	0.51	0.66	0.65	0.61	3.00

Distribution (Fig. 17). Although originally described from (the present) Lake Pedder, this species was recorded from three additional localities by Smith (1979). These are: small perched lake, just upstream from Butlers Island, lower Gordon River (confirmed as *G. pedderi*); Cleveland, W. Tasmania (material not seen but, judging from the locality, it is probably *G. decoratus*); Dip River Falls, NW Tasmania

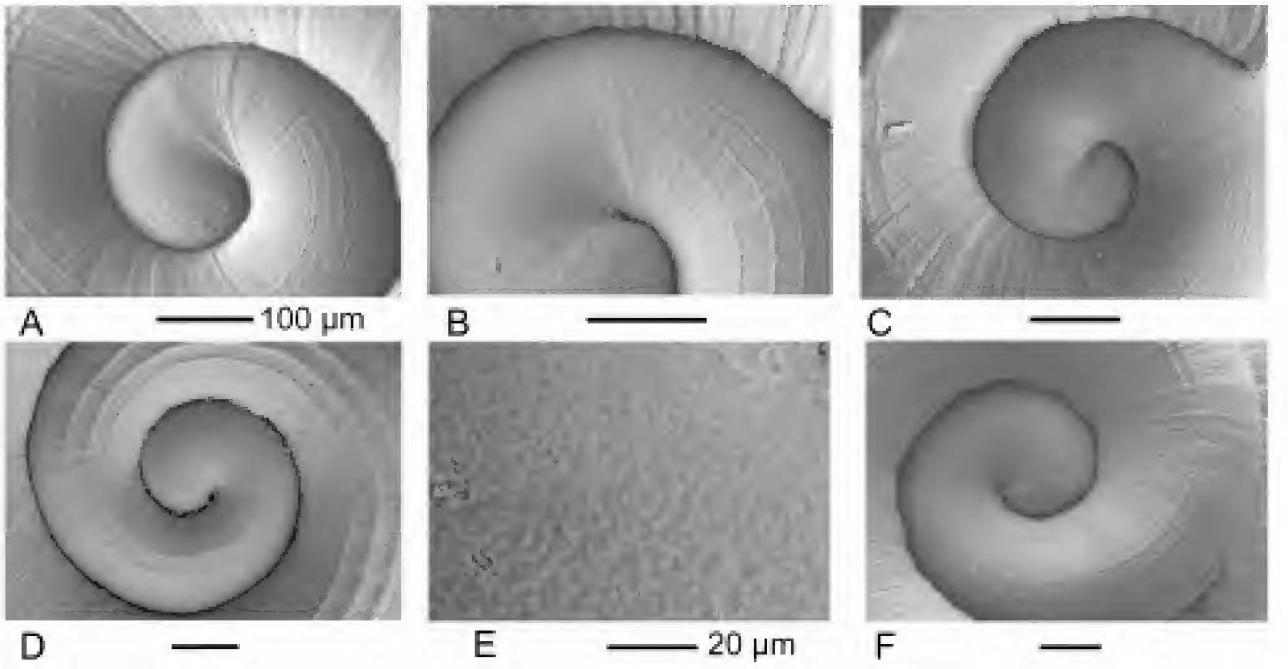

Figure 18. Protoconchs of *Striadorbis*. A–C,F: *Striadorbis pedderi*. A: tributary of Split Rock Ck, 2.8 km NE of Liawenee on Lake Hwy, Tasmania (AMS C350048). B: Gordon River just below Camerons Flat, SW Tasmania (AMS C350020). C,F: NE of Harlequin Hill 850 m off Scotts Peak Rd, SW Tasmania (AMS C202191); dorsal (C) and ventral (F) views. D,E: *Striadorbis spiralis* n.sp.; Fitzroy River on Princes Hwy between Portland and Port Fairy, Victoria (paratype, AMS C351209); detail of microsculpture on initial whorl (E). Scale bars for A–D and F 100 µm.

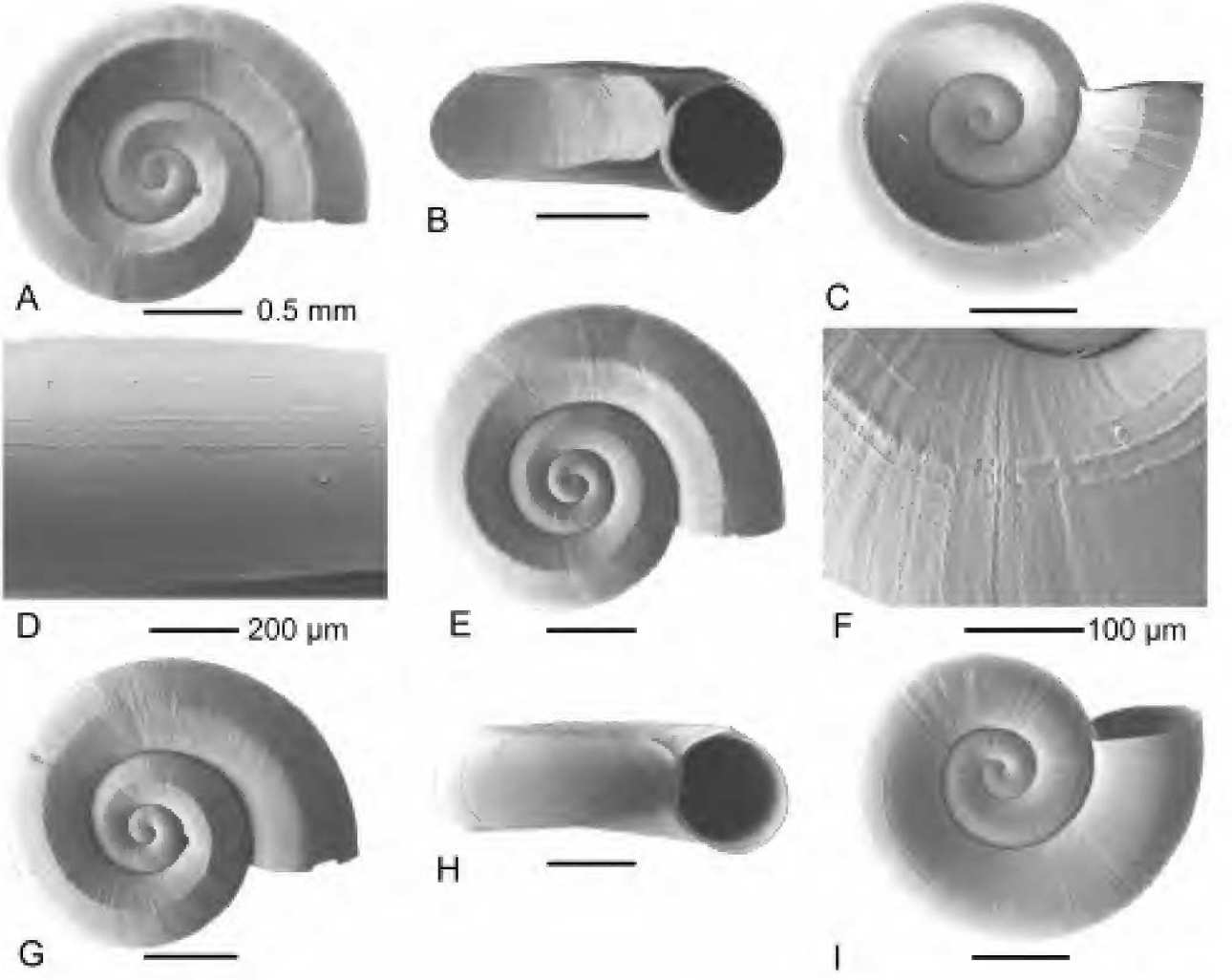

Figure 19. Shells of *Striadorbis pedderi*. A–C: NE of Harlequin Hill 850 m off Scotts Peak Rd, SW Tasmania (AMS C202191); dorsal, lateral and ventral views. D–F,H,I: Gordon River just below Camerons Flat, SW Tasmania (AMS C350020); detail of sculpture on periphery (D). E,H,I: dorsal, lateral and ventral views. F: detail of sculpture on ventral side of last whorl of a subadult. G: tributary of Split Rock Ck, 2.8 km NE of Liawenee on Lake Hwy, Tasmania (1, AMS C350048); dorsal view. Scale bars A–C, E, G–I 0.5 mm.

(*Glacidorbis atrophus*). These localities were mapped in Smith & Kershaw (1981).

Remarks. Smith (1973) described the shell surface as being composed of an "irregular lattice of crystal elements". In fact, the surface of the holotype is corroded (see also Smith, 1973, fig. 5). The radular mount illustrated by Smith (1973) does not show the lateral elements clearly, although their presence is suggested in his figs. 7 and 9. Smith (1973, 1979) and Ponder (1986) did not record ovovivipary in this species and, as it has not been seen it in the specimens examined in this study, it appears that it does not brood capsules.

Some specimens differ from typical *T. pedderi* in having a weak basal ridge (Fig. 19 I), weaker dorsal keel (Fig. 19H) and more distinct spiral threads over most of the teleoconch surface (Fig. 19H–I). Intermediate examples are found and there is no clear cut geographic pattern so these morphs are considered to be conspecific.

Striadorbis spiralis n.sp.

Derivation: *spiralis* (Latin)—spiral.

Type material. HOLOTYPE, AMS C350959. PARATYPES: many, AMS C351209; 7, AMS C302484; 1, AMS C302485; 1, AMS C353965; 4, MV F82299.

Type locality. Stn WVIC13, Fitzroy River on Princes Hwy between Portland and Port Fairy, Victoria, 38°13.29'S 141°45.79'E, amongst roots of willows and *Leptospermum*, 4 Jan 1999, WFP.

Additional paratypes. Stn VIC26, Fitzroy River at Princes Hwy, E of Portland, Victoria, 38°13.51'S 141°45.61'E, in roots and weed, 18 Feb 1994, 10, GAC & ACM, pH 7.79, cond. 1.93 (7, AMS C302484; 2, AMS C302485; 1, AMS C350959; 1, AMS C353965).

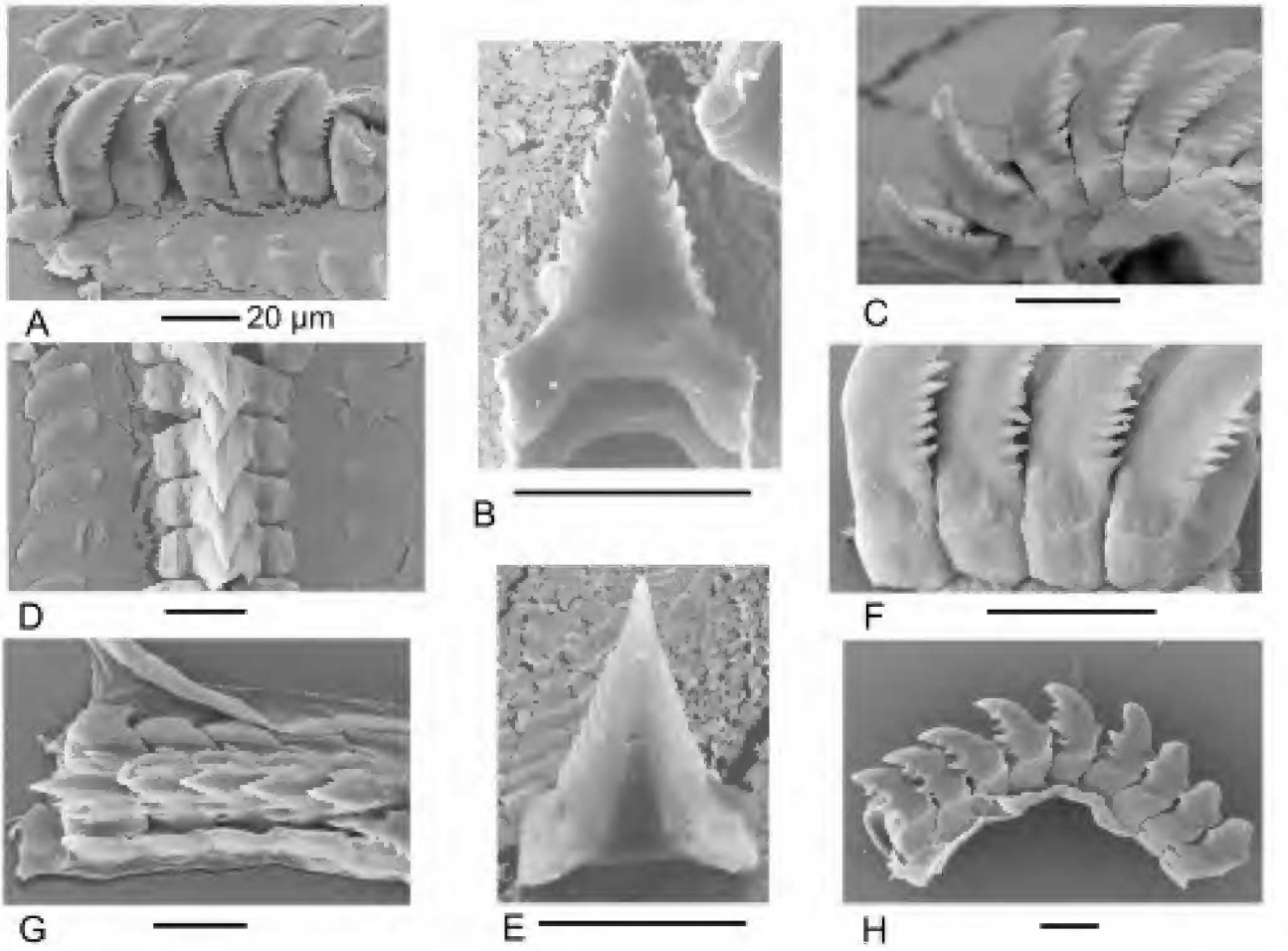

Figure 20. Radulae of *Striadorbis* and *Tasmodorbis*. A,D,F: *Striadorbis pedderi*; NE of Harlequin Hill 850 m off Scotts Peak Rd, SW Tasmania (AMS C202191); lateral (A,F) and dorsal (D) views. B,C,E: *Striadorbis spiralis* n.sp.; Fitzroy River on Princes Hwy between Portland and Port Fairy, Victoria (paratypes, AMS C351209); lateral view (C) and separate teeth, anterior face (B), posterior face (E). G,H: *Tasmodorbis punctatus* n.sp.; tributary Lockwood Ck, near end of Lockwood Creek Rd, NW Tasmania (AMS C364664); dorsal and lateral views.

Diagnosis. Shell with evenly convex whorls having 3–4 strong spiral threads on upper and lower surfaces that persist over whole shell, as well as several weaker spirals; periphery lacking spiral threads.

Description. Shell (Figs. 18D,E; 21A–C) very small (up to 1.2 mm in max. diameter), planispiral, of about 2.4 whorls. Protoconch (Fig. 16D,E) of 1.3 whorls, first ⅓ whorl sculptured with minute pustules, remaining whorl with 3 strong and 1 weaker spiral threads. Teleoconch sculpture of 2–3 strong spiral threads on middle of both dorsal and ventral surfaces; a few (1–3) weaker threads also present on outside and 0–2 inside strong spirals. Dorsal and ventral surfaces of whorls convex; periphery of last whorl evenly convex, smooth. Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.69–0.71. Aperture near circular (type material and 3 specimens from AMS C302485 examined using SEM). Colour pale yellow to orange brown, semi-transparent.

Dimensions. See Table 20.

Operculum (Fig. 16D) circular, concave, of c. 4.6 (adult 2.6) overlapping whorls, width of last whorl/length of operculum 0.28–0.29. Nucleus large, 0.28–0.29 length of operculum, spiral (about 2 whorls), central. Inner surface simple. Exterior with several very irregular rows of spirally arranged pustules on last whorl (examined using SEM from 2 specimens from type locality).

Radula (Fig. 20B,C,E) of 17+ rows. Central teeth with 6–8 (usually 7) sharp, approximately equal-sized lateral cusps occupying about ⅔ length of mesocone. Base 2.7–2.8 wider than long, about 1.6 wider than width of mesocone, outer edges slightly concave, dorsal basal thickening rather weak, anterior articulatory thickening weaker than posterior, anterior articulation overlapped slightly by tooth in front. Details of lateral elements not available from mount (2 specimens examined using SEM from type locality).

Several preserved specimens were examined and none contained brooded embryos. The head-foot is unpigmented and the body (as seen through the shell) is covered with small black blotches.

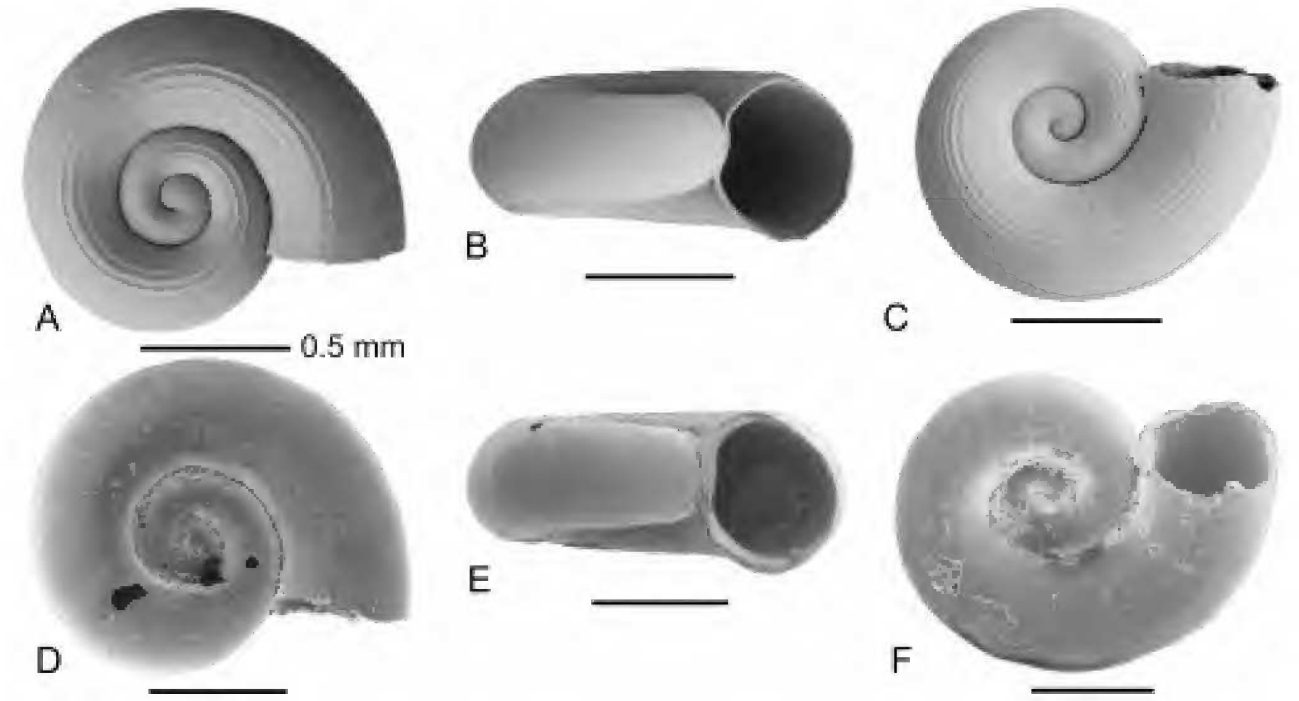

Figure 21. Shells of *Striadorbis*. A–C: *Striadorbis spiralis* n.sp.; dorsal view of holotype (A) (AMS C350959). B,C: Fitzroy River on Princes Hwy between Portland and Port Fairy, Victoria (paratypes, AMS C351209); lateral and ventral views of two specimens. D–F: *Striadorbis janetae* n.sp.; holotype (AMS C369814); dorsal, lateral and ventral views.

Table 20. Shell measurements of types of *Striadorbis spiralis*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype						
0.87	1.06	0.26	0.50	0.46	0.37	2.60
figured paratype (AMS C351209)						
0.78	0.96	0.25	0.41	0.41	0.33	2.20
paratype (AMS C350959)						
1.21	1.43	0.41	0.63	0.57	0.48	2.40
paratypes (AMS C302485)						
0.86	1.05	0.29	0.49	0.48	0.41	2.20
0.90	1.17	0.30	0.49	0.47	0.42	2.25

Distribution (Fig. 17). Known only from the one locality in the Fitzroy River, Western Victoria.

Remarks. This species is placed in *Striadorbis* because its protoconch and opercular characters closely resemble those of *T. pedderi*. It differs from that species in lacking a distinct dorsal and ventral keel, in having several distinct spiral ridges and in lacking spiral threads on the periphery.

While this species appears to have a restricted distribution, more sampling is required in the area to ascertain its actual range. Extensive sampling by WFP in the Fitzroy River further upstream in the vicinity of Heywood failed to locate this species.

Striadorbis janetae n.sp.

Derivation. Named for Janet MacIntosh (née Waterhouse) in recognition of her expertise in collecting glacidorbids.

Type material. HOLOTYPE, AMS C369814. PARATYPE (1): AMS C363861.

Type locality. Stn TA99, Last River, tributary of Ansons R on Ansons Bay Rd, Tasmania, 41°8.2'S 148°11.7'E, 80 m, 31 Jan 1987, WFP JHW & GAC, pH 6.75, cond. 0.18 (AMS C363861).

Additional material examined. TASMANIA: Stn C68T, Apsley River on Hwy 3, 41°54'S 148°15'E, on stones and weed, 16 Jan 1982, 15, WFP JH & WFPj (1, AMS C202174).

Diagnosis. Shell with slightly angulated whorls having one strong spiral thread on upper and lower surfaces that persists over whole shell, as well as several weaker spirals; periphery smooth.

Description. Shell (Figs. 21D–F) very small (up to 1.5 mm in max. diameter), planispiral, of about 2.5 whorls. Protoconch of about whorls, first third whorl sculptured with minute pustules, remainder of whorl with two moderately strong spiral threads (protoconch details from AMS C202174). Teleoconch sculpture of one strong spiral thread at middle of both dorsal and ventral surfaces forming weak subangulation; 2–3 weaker spiral threads also present inside and 5–6 outside main spiral dorsally and 3–5 inside

and up to 8 outside ventrally. Dorsal and ventral surfaces of whorls convex; periphery of last whorl evenly convex, smooth. Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter 0.70–0.75. Aperture near circular (holotype and specimen from AMS C202174 examined using SEM). Colour yellowish-white.

Dimensions. See Table 21.

Table 21. Shell measurements of the types of *Striadorbis janetae*.

dmin	dmax	dht	mxht	aph	apw	whl
holotype						
1.21	1.50	0.39	0.55	0.64	0.53	2.5
additional specimen AMS C202174						
0.93	1.14	0.34	0.47	0.48	0.40	2.3

Operculum (Fig. 16E) circular, slightly concave, of c. 4.5 (adult 2.5) overlapping whorls, width of last whorl/ length of operculum 0.19. Nucleus large, about 0.33 length of operculum, spiral (about 2 whorls), central. Inner surface not examined. Exterior with several irregular rows of spirally arranged pustules on last whorl (operculum of holotype examined using SEM).

Radula. Not examined.

Head-foot. Unpigmented.

Distribution (Fig. 17). NE coast, in eastward-flowing drainages.

Remarks. This Tasmanian species resembles the western Victorian *S. spiralis*, the shell differing in having a single spiral thread (not 2) dominating dorsally and ventrally. This spiral weakly subangulates the whorl above and below while in *S. spiralis* the dorsal and ventral surfaces of the whorls are evenly convex. *Striadorbis janetae* differs from *S. pedderi* in having weakly subangled whorls dorsally and ventrally (not strongly keeled), in being smaller, in having the secondary spirals more strongly developed and lacking spiral threads on the periphery.

The material for this species is poor. The holotype, being only one of two specimens available from the type locality. Only one other specimen is assigned to this species. It is from the Apsley River, a catchment further south than the type locality, but also an east coast drainage. The holotype has a weaker median spiral than the Apsley River specimen. The holotype has 3 spiral threads inside the main dorsal spiral and 6 outside and, on the base, has 5 outside and 8 inside. The Apsley River specimen (which is smaller and probably somewhat immature) has 2 spirals inside and 5 outside the main dorsal spiral and 3 inside and 2 outside the primary basal spiral. The greatly increased number of spirals on the base in the type are attributable to the spirals continuing onto the inner base, the inner-most next to the suture, whereas in the Apsley River specimen the spirals are confined to the middle part of the whorl. The determination of the significance of these differences will have to await examination of additional material.

Tasmodorbis n.gen.

Derivation: *tasmo*—derived from Tasmania; *dorbis*—derived from *Glacidorbis*.

Type species: *Tasmodorbis punctatus* n.sp.

Diagnosis. Shell planorbid-like, planispiral to slightly hyperstrophic, protoconch with initial part distinctly inclined downwards, sculptured with close rounded axial ribs and very close, even spiral threads. Rest of shell simple, with convex whorls and close collabral growth lines, less tightly coiled than in other members of family. Interior of shell with shell pores. Radula similar to *Glacidorbis* but with one (or rarely two) cusps at lower ⅓ of mesocone much larger than others and base with articulatory elements thrust forwards so point of articulation lies beneath middle of tooth in front. Base not acutely expanded, shape of tooth approximately triangular. Lateral elements similar to *Glacidorbis*, untanned, broad, about as long as base of central teeth. Operculum circular, multispiral and lacking pustules on external surface. Anatomy unknown.

Remarks. This genus differs from *Glacidorbis* and other glacidorbid genera in at least four important characters: (*a*) the nature of the axial and spiral microsculpture on the protoconch, (*b*) the details of the central teeth (see diagnosis), (*c*) the circular, multispiral operculum and (*d*) the shell pores on the inner surface of the shell. *Striadorbis* has a circular operculum but in that genus it is paucispiral. No other glacidorbid has shell pores, protoconch microsculpture or radular characters like *T. punctatus*. The shell coiling is also looser than in other glacidorbids. As in species of *Benthodorbis*, there is no distinct umbilical area because of the very shallow, slightly concave base.

The articulation of the teeth bases is unlike other Australian members of the family but possibly resembles that in *Gondwanorbis magallanicus* (see Meier-Brook & Smith, 1976, fig. 4).

The shell pores are, as far as is known (condition in *Gondwanorbis* unknown), unique in this family and are possessed by relatively few gastropods (see Reindl & Haszprunar, 1994 for a recent review). They are illustrated in Figures 22G–I, K. Each consists of an expanded, cone-like entrance (Fig. 22H,K) constricting to a narrow, straight tube that penetrates deep into the shell (Fig. 22G,I). These tubes were not traced to the surface in the preparations examined and no openings were visible on the outer surface.

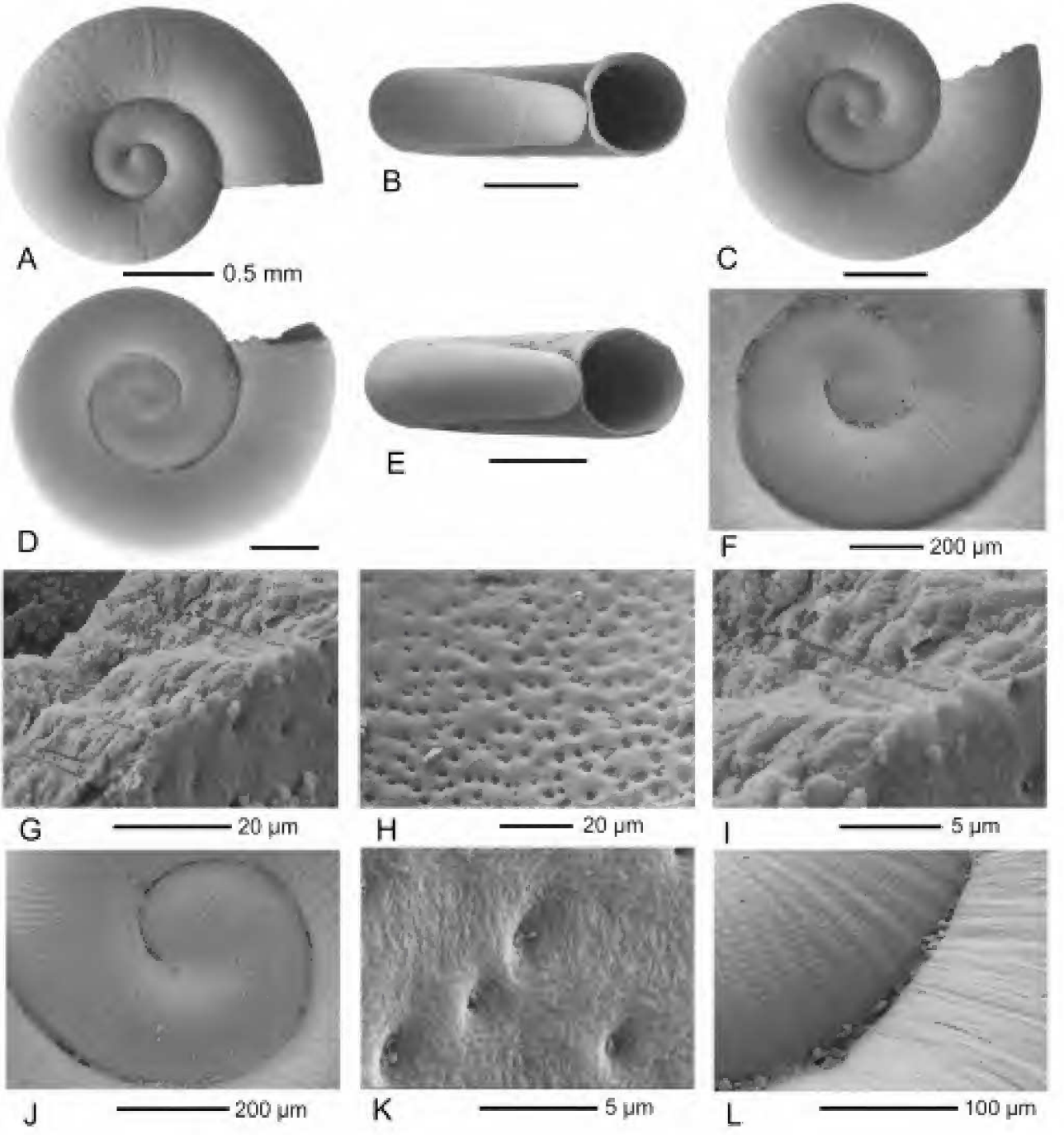

Figure 22. Shell of *Tasmodorbis punctatus* n.sp. A: holotype (AMS C351678); dorsal view. B–L: Wandle River on Murchison Hwy, N of Waratah, NW Tasmania (AMS C202187). B–E: lateral and ventral views of four specimens. F: ventral view of protoconch. G,I: fractured shell surface at different magnifications showing tubes through shell from punctures. H,K: punctures on inner surface of shell. K: shows high power detail. J: dorsal view of protoconch. L: detail of sculpture on latter part of protoconch and early teleoconch.

Tasmodorbis punctatus n.sp.

Derivation: *punctatus* (Latin)—small puncture.

Type material. HOLOTYPE, AMS C351678. PARATYPES (9): 7, AMS C202187; 1, TM E23421; 1, QVM 9:16235.

Type locality. Stn C139T, Wandle River on Murchison Hwy, N of Waratah, Tasmania, 41°21.81'S 145°34.83'E, 565 m, on weed and roots and on and under stones, 23 Jan 1982, 565, WFP JH & WFPj.

Additional material examined. TASMANIA: stn TA526B, tributary Lockwood Ck, near end of Lockwood Creek Rd, 41°16'S 145°40'E, 540 m, leaf litter, 7 Feb 1989, WFP JHW & FEH, pH 6.21, cond. 0.07 (16 [decalcified—radula examined], AMS C364664); stn C140T, Deep Gully Creek, tributary of Arthur River, at Murchison Hwy, 41°25.467'S 145°33.7'E, rocks and gravel in large stream, 23 Jan 1982, WFP WFPj & JH (4, AMS C366183); stn JW19, Lake Butters, E of Walls of Jerusalem, 41°48.9'S 146°22.6'E, 1250 m, rocky, cobbly shoreline, 5 Feb 1988, JHW (3, AMS C355560) (with *S. pedderi*); stn TA628C, tributary of Gordon River, 1.2 km N of Snag Point on W side of river, 42°31.383'S 145°40.067'E, 40 m, in seepage, 15 Feb 1989, WFP & FEH (2, AMS C354938).

Diagnosis. Shell smooth, more loosely coiled than other members of family, with punctures on inner shell surface and multispiral operculum.

Description. Shell (Fig. 22) small (up to 2.1 mm in max. diameter), normally planispiral, of about 2.3 convex whorls. Protoconch of 1.4 whorls, initial part strongly inclined downwards, sculptured with low, narrow, rounded axial folds crossed by numerous spiral threads with linear interspaces which form tiny rectangular pustules at intersections. Teleoconch sculpture of fine, irregular axial growth lines. Dorsal surface of whorls convex near suture, sutures impressed; periphery of last whorl evenly convex; ventral surface of last whorl convex. Base with broad, shallow umbilicus; ratio of umbilical width to maximum diameter about 0.70. Aperture circular (examined using SEM from type locality). Colour dark brown, with last part of last whorl yellow-white.

Dimensions. See Table 22.

Operculum (Fig. 16G–I) circular, concave, of c. 7 overlapping whorls with edges frilled, width of last whorl/length of operculum 0.06. Nucleus large, 0.32–0.37 length of operculum, central. Inner surface with slightly raised spiral ridge surrounding nucleus. Exterior with overlapping edges of each whorl; otherwise smooth (examined from 3 specimens from type locality and AMS C202187).

Radula (Fig. 20G,H) of 17 rows (from one specimen only). Central teeth with 2–3 sharp, approximately equal-sized lateral cusps above one large cusp (2–3x length of cusp above) at lower ⅓ with 1–2 cusps below; upper most of basal cusps sometimes large, rarely as large as major cusp above it. All cusps occupy about ⅔ length of mesocone. Base about 1.58 wider than long, about 1.67 wider than width of mesocone, outer edges lightly convex, dorsal basal thickening prominent, anterior articulatory thickening thrust forwards, abutting strongly concave posterior articulatory thickening that lies beneath mesocone of next tooth. Width of lateral elements about half length, straight laterally, with slightly thickened inner ends; narrow spaces between each element (examined from 1 specimen, AMS C364664 and 1 from type locality).

Distribution (Fig. 17). Western Tasmania.

Remarks. The specimen illustrated in Fig. 22B shows slight hyperstrophic coiling but other specimens are planispiral or nearly planispiral (e.g., Fig. 22E).

Table 22. Shell measurements of the types of *T. punctatus*.

dmin	dmax	mdht	mxht	aph	apw	whl
holotype						
1.45	1.72	0.40	0.60	0.60	0.54	2.00
paratypes (AMS C202187)						
1.67	1.99	0.43	0.66	0.65	0.59	2.10
1.48	1.74	0.37	0.59	0.57	0.52	2.20
1.26	1.52	0.36	0.55	0.54	0.54	2.00
1.09	1.34	0.30	0.49	0.44	0.48	1.95
1.17	1.42	0.33	0.54	0.54	0.48	1.85
1.24	1.53	0.34	0.58	0.57	0.52	1.90
1.83	2.09	0.50	0.65	0.64	0.62	2.45

Gondwanorbis Ponder, 1986

Type species. *Glacidorbis magallanicus* Meier-Brook & Smith, 1976, Chile.

Originally proposed as a subgenus, *Gondwanorbis* was raised to generic rank by Starobogatov (1988). Diagnostic characters that were originally given were the peripheral keel on the shell and the base of central radular teeth being about twice as wide as the mesocone and the radula with or without a pair of vestigial lateral teeth. To this can be added the circular, paucispiral operculum with a central nucleus (Meier-Brook & Smith, 1976, fig. 3), a character shared with *Striadorbis*, although it is not known if the South American taxon has external pustules on the operculum. The articulation of the teeth appears to be similar to that seen in *Glacidorbis* (Meier-Brook & Smith, 1976, fig. 4).

Discussion

Relationships within the family. Bunn & Stoddart (1983) used a Wagner network in an attempt to indicate "relationships" of the five living species included in *Glacidorbis* at the time. Their diagram shows *G. occidentalis* and *"G." pedderi* as sister taxa, *G. hedleyi* and *"G." magallanicus* as sisters and *"G." pawpela* as well removed from the other taxa. The data used in their phenetic analysis consisted of six characters, two shell characters (maximum diameter and presence of keel) and four radular characters (average teeth rows, average cusps per side, presence of marginal teeth, and tooth height/depth at base).

A cladistic analysis of relationships using parsimony methods is given below. The lack of anatomical data for all but two taxa necessitates an analysis using only radular, shell and opercular characters. The characters and their states used are as follows:

Shell characters

1 Dorsal keel. 0—absent, 1—present.
2 Strength of dorsal keel. 0—weak angulation, 1—moderate, 2—strong, dash—inapplicable.
3 Ventral keel or angulation in middle to inner quarter of base. 0—absent, 1—present.
4 Peripheral keel. 0—absent, 1—present (autapomorphy of *Gondwanorbis*).
5 Development of ventral keel or angulation in middle to inner quarter of base. 0—only weak angulation or ridge, 1—strong keel, dash—inapplicable.
6 Position of dorsal keel or angulation. 0—in middle of whorl, 1—in inner third to quarter, dash—inapplicable.
7 Position of ventral keel or angulation. 0—in middle of whorl, 1—in inner third to quarter, dash—inapplicable.
8 Keel or ridge in outer ⅓ of base. 0—absent, 1—present (autapomorphy of *B. fultoni*).
9 Spiral threads or cords on dorsal (and ventral) surface. 0—absent, 1—present.
10 Strength of spirals. 0—subobsolete, 1—weak to moderate threads, 2—strong cords, dash—inapplicable.
11 Spiral threads or cords on periphery. 0—absent, 1—present.
12 Axial costate present. 0—absent, 1—present.
13 Distribution of axial costae. 0—confined to early teleoconch whorls, 1—over whole shell surface, dash—inapplicable.
14 Coiling pattern. 0—orthostrophic, 1—planispiral, 2—hyperstrophic.
15 Protoconch apical sculpture. 0—granules, 1—punctures, 2—spiral and axial threads.
16 Secondary protoconch sculpture. 0—smooth except for axial threads, 1—with spirals.
17 Shell punctures. 0—absent, 1—present (autapomorphy of *Tasmodorbis*).
18 Growth lines. 0—orthocline, 1—prosocline.

Opercular characters

19 Opercular shape. 0—oval, nucleus eccentric to subcentral; 1—circular with central nucleus.
20 Number of opercular spirals. 0—few (less than 4), 1—4 or more.
21 Opercular sculpture on outer surface. 0—smooth, 1—with granules.
22 Opercular whorl overlap. 0—little or no overlap, 1—whorls overlapping.

Radular characters

23 Radular base. 0—expanded acutely beyond mesocone; 1—not acutely expanded, approximately triangular in outline.
24 Cusp pattern. 0—even, 1—one cusp much larger (autapomorphy of *Tasmodorbis*).
25 Articulation of teeth. 0—anterior stronger, or subequal to posterior; 1—posterior stronger.

Table 23. The data matrix used in the cladistic analysis. The character numbers correspond to those listed in the text. Dash = inapplicable, ? = unknown.

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Gondwanorbis	0	–	0	1	0	–	–	0	0	–	0	0	–	1	?	?	?	0	1	1	?	0	?	0	0
Glacidorbis hedleyi	0/1	0	0	0	0	–	–	0	0	–	0	0	–	0	0	0	0	0	0	0	1	0	0	0	0
Glacidorbis catomus	1	1	1	0	0/1	0/1	0	0	0	–	0	0	–	0	1	0	0	0	0	0	1	0	0	0	0
Glacidorbis bicarinatus	1	2	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0
Glacidorbis atrophus	1	2	1	0	0	0	1	0	0	–	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0
Glacidorbis decoratus	1	2	1	0	0	1	1	0	0	–	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0
Glacidorbis otwayensis	1	0/1	1	0	0	0	1	0	0	–	0	0	–	0	1	0	0	0	?	?	?	?	?	?	?
Glacidorbis rusticus	1	2	1	0	0	1	1	0	0	–	0	0	–	0	1	0	0	0	0	0	1	0	0	0	0
Glacidorbis tasmanicus	0/1	0	0	0	–	–	–	0	0	–	0	0	–	0	1	0	0	0	0	0	1	0	0	0	0
Glacidorbis costatus	0	–	0	0	–	–	–	0	0	–	0	1	1	0	1	0	0	0	?	?	?	?	?	?	?
Glacidorbis occidentalis	0	–	0	0	–	–	–	0	0	–	0	0	–	0	1	0	0	0	0	0	1	0	0	0	0
Glacidorbis troglodytes	0	–	0	0	–	–	–	0	0	–	0/1	0	–	0/2	1	0	0	0	?	?	?	?	?	?	?
Glacidorbis circulus	1	1	1	0	1	0	1	0	1	2	0	0	–	0	1	0	0	0	0	0	1	?	?	?	?
Glacidorbis isolatus	1	2	1	0	1	1	0	0	0	–	0	0	–	0	0	0	0	0	0	0	1	?	0	?	?
Striadorbis pedderi	1	2	1	0	0	0/1	0	0	1	1	1	0	–	1	0	1	0	0	1	1	1	0	0	0	1
Striadorbis spiralis	0	–	0	0	–	0	–	0	1	2	0	0	–	1	0	1	0	0	1	1	1	0	0	0	1
Striadorbis janetae	1	1	1	0	0	0	0	0	1	2	0	0	–	1	?	1	0	0	1	?	1	?	?	?	?
Benthodorbis pawpela	0	–	0	0	–	–	–	0	1	1	1	0	–	2	0	1	0	1	0	0	?	1	1	0	0
Benthodorbis fultoni	0	–	0	0	–	–	–	0/1	1	1	1	0	–	2	0	1	0	1	0	0	0	1	?	0	0
Tasmodorbis punctatus	0	–	0	0	–	–	–	0	0	0	0	0	–	1/2	0	1	1	0	1	1	0	1	1	1	0

The data matrix used is given in Table 23. This was analysed using using the default heuristic search options in PAUP* and 10 random iterations.

In the analysis (all characters unordered and unweighted) 7236 equally parsimonious trees were generated [length 45, Consistency Index (CI) 0.60, Homoplasy Index (HI) 0.40, Retention Index (RI) 0.75, Rescaled Consistency Index (RC) 0.45]. Despite the large number of trees, the resulting strict consensus tree supported the generic groupings (Fig. 23). The tree consists of three clades—one being *Striadorbis* with *S. spiralis* basal, the second comprising *Benthodorbis* and *Tasmodorbis*, and the third *Glacidorbis* (Bremer support values are given in Fig. 23). *Striadorbis* is supported by four characters, dorsal shell keels (2), spiral sculpture on the teleoconch (9, 10), and the third the articulation of the radula (25). The *Benthodorbis* + *Tasmodorbis* clade is supported by four supposedly synapomorphic character states that are shown as reversals in the analysis but are probably all plesiomorphic: 14,1 (planispiral coiling pattern—the condition in the outgroup), 21 (lack of opercular sculpture—condition not known in outgroup but absent in other operculate heterobranchs so presumably actually plesiomorphic), 22,1 (opercular whorl overlap—condition in outgroup unknown but this is probably the plesiomorphic condition in other gastropods) and 23,1 (radular base not expanded—although the outgroup has a widely expanded base, this is not the case with most other heterobranch groups).

Two autapomorphies support *Tasmodorbis* (17,1—shell punctures and 24,1—uneven radular cusp pattern). *Benthodorbis* is supported by one autapomorphy (18,1—prosocline growth lines) and five homoplastic apomorphies related to spiral sculpture on the teleoconch (9,1, 10,1 and 11,1) and the operculum (19,0 and 20,0).

Glacidorbis is supported by two synapomorphic character states (14,0—orthostrophic shell shape and 16,1—smooth secondary protoconch). The available data are not sufficiently robust to allow an assessment of the relationships within *Glacidorbis*, the only clade being supported in the strict consensus tree consisting of species similar to *G. bicarinatus*, together with *G. isolatus* and *G. circulus*. This node is supported by three homoplastic shell characters (1, 2, 5) all related to dorsal and ventral keels. While the dorsal and ventral keels co-occur in nearly all keeled taxa within *Glacidorbis*, the degree of their development is not entirely correlated, nor is their location on the shell. It is for this reason that six characters involving dorsal and ventral keels were scored. However, this has resulted in these largely correlated characters dominating the analysis. *Glacidorbis isolatus* is, for example, grouped with the other keeled species but this species shares granulate protoconch microsculpture with *G. hedleyi*, and these are the only taxa occurring in New South Wales, the remaining taxa having punctate protoconch sculpture.

The analyses are limited in that no anatomical characters could be used because of lack of data and because of the lack of information in some key characters concerning the outgroup. While the results support the monophyly of the generic groupings used, the sister group relationship identified for *Tasmodorbis* and *Benthodorbis* may not be supported once additional data are available.

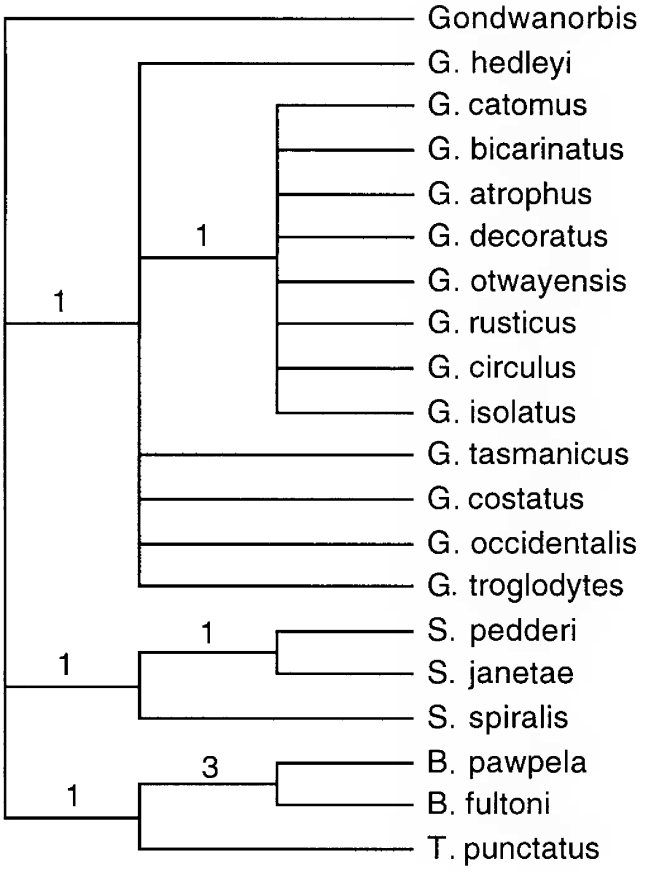

Figure 23. Strict consensus of the shortest trees produced from the data in Table 23. All characters are unordered and unweighted. The level of Bremer support is indicated at each node.

Biogeography. The biogeography of this group, based on the small number of taxa previously known, has been briefly discussed by Meier-Brook & Smith (1976) and Bănărescu (1990). The majority of species occur in northern and western Tasmania, with a few taxa in Victoria, eastern-most South Australia and New South Wales. In general, the distribution of glacidorbids in Tasmania shows a somewhat similar pattern to hydrobiid gastropods of the *Beddomeia* group (Ponder *et al.*, 1993). Species of *Glacidorbis* occur across the northern third of the island while *Tasmodorbis* is restricted to the western part of Tasmania. *Striadorbis pedderi* is also found in the western part of Tasmania but extends further to the east than *Tasmodorbis*. The other Tasmanian species of *Striadorbis* is found on the northern half of the east coast, the remaining species being found in western Victoria. With the exception of this latter species, the other glacidorbids found on the mainland are species of *Glacidorbis*. They are found in swamps and streams along the Great Divide and in nearby high country in New South Wales and Victoria (*G. hedleyi, G. isolatus*), or in coastal drainages in Victoria or just across the border in South Australia (*G. troglodytes, G. rusticus, G. otwayensis*) and in south Western Australia (*G. occidentalis*). *Benthodorbis* is restricted to two of the older lakes in Tasmania, this

apparent genus-level endemism in these lakes not being reflected in hydrobiids. While the above distribution patterns are unlikely to change substantially, these tiny animals are easily missed and additional collecting will probably change the detail. The lack of glacidorbids from mainland inland, northern and north eastern drainages is probably real, given the extensive collecting in these areas for small freshwater molluscs in recent years.

Species occupy wider ranges than seen in many hydrobiids (Ponder, 1994 and references therein). Nevertheless, a few species appear to be restricted in range (see Conservation below). There are few records of glacidorbids occurring in sympatry and, when they do, the taxa are not congeneric.

Ecology and biology. Relatively few observations have been made on the ecology of species of glacidorbids but the species clearly occupy a wide range of habitats from swamps and bogs to streams and rivers. They are normally found on macrophytes and other vegetation such as moss or roots, on pieces of wood, or, more rarely, under stones. The two species of *Benthodorbis* live on sediment on the bottom of lakes. Some, such as *G. hedleyi,* are tolerant of a wide range of temperature, conductivity, dissolved oxygen and pH (Boulton & Smith, 1985: pH values ranging from 4.8–7.6, temperature from 2–21°C, dissolved oxygen 1.2–15.0 ppm and conductivity 48–225 µS/cm). Bunn & Stoddart (1983) give a range of pH 6.3–6.4 for *G. occidentalis*.

An analysis of the 112 records of pH for glacidorbids in the Australian Museum collections shows a range from 4.85 to 8.00 (mean 6.392) and for conductivity a range of 0.01–1.93 (mean 0.264, n = 108) (see Table 24 for species level summary).

Glacidorbis occidentalis lives in intermittent streams (Bunn *et al.*, 1989) and *G. hedleyi* is also known to occur in intermittent habitats (Boulton & Smith, 1985) but most of the other species appear to live in permanent to semi-permanent streams and swamps.

Glacidorbis hedleyi was shown to be a carnivore (Ponder, 1986) but no observations on the food or feeding of other species have been made. The occurrence of large numbers of *Pinus* pollen grains in the digestive gland of *G. occidentalis* suggests the interesting possibility that this species may be feeding, at least in part, on pollen.

To date, only two species have been definitely confirmed as brooding young; *Glacidorbis hedleyi* and *Benthodorbis pawpela*. In this study each species has not been examined systematically, mainly because available material is limited. The unusual reproductive mode seen in *G. hedleyi* (Ponder, 1986), in which protandric males have to copulate before turning into females, warrants comparative investigation of other taxa.

Conservation. The conservation of small, narrow-range freshwater molluscs in Australia has been highlighted by Ponder (1994). Some species of *Glacidorbis* have restricted ranges, and one (*G. costatus*) appears to be extinct, probably as a result of the draining of Pulbeena Swamp for farming and mining. *Glacidorbis troglodytes* and *G. spiralis* are also only known from single locations but may be found to have, at least, slightly wider distributions. In the case of *G. troglodytes*, other sink holes in the Mt Gambier area have not been adequately examined and *G. spiralis* undoubtedly has a more extensive distribution within the Franklin River than the available sampling indicates. *Glacidorbis circulus* is known from only two locations on Marine Creek on the mid north coast of Tasmania. The only other taxa restricted to single locations are the species of *Benthodorbis*, both found in single lakes (Great Lake and Lake Sorell). Both these species are found on soft sediment on the lake bottom and could be susceptible to damage from introduced carp (*Cyprinus carpio* L.). All other taxa are more widely distributed, with the most widespread taxon being *G. hedleyi*.

Table 24. Summary of pH and conductivity records in the Australian Museum collections for glacidorbid taxa. The range (mean) and ± standard deviation are given. Each record represents a single reading.

taxon	n	pH	n	conductivity
Glacidorbis	95	4.85–7.65 (6.343)±0.526	94	0.01–0.84 (0.210)±0.203
Glacidorbis atrophus	6	6.07–6.59 (6.208)±0.224	6	0.05–0.14 (0.113)±0.042
Glacidorbis bicarinatus	8	6.00–6.42 (6.262)±0.181	7	0.06–0.10 (0.067)±0.015
Glacidorbis catomus	10	5.62–7.65 (6.552)±0.577	13	0.07–0.79 (0.225)±0.190
Glacidorbis circulus	3	6.50–7.58 (6.860)±0.624	3	0.09
Glacidorbis decoratus	14	5.60–6.68 (6.036)±0.273	10	0.50–0.21 (0.103)±0.052
Glacidorbis hedleyi	14	6.10–7.34 (6.673)±0.395	14	0.02–0.14 (0.058)±0.040
Glacidorbis otwayensis	2	6.20–6.65 (6.425)±0.318	2	0.10
Glacidorbis rusticus	27	5.30–7.46 (6.120)±0.510	28	0.20–0.84 (0.444)±0.180
Glacidorbis tasmanicus	11	4.85–7.26 (6.645)±0.725	11	0.01–0.22 (0.082)±0.069
Striadorbis	15	5.50–8.00 (6.682)±0.844	9	0.01–1.93 (0.716)±0.899
Striadorbis janetae	2	6.00–6.75 (6.375)±0.530	1	0.18
Striadorbis pedderi	12	5.50–8.00 (6.390)±0.762	7	0.01–0.23 (0.099)±0.078
Striadorbis spiralis	1	7.71	1	1.93
Tasmodorbis	2	6.21–6.47 (6.34)±0.184	2	0.07–0.08 (0.075)±0.007

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Taxonomic index